Research Note 84-140

AD-A149 484

INSTRUCTIONAL MATERIALS: LIFE CYCLE COST ANALYSIS FOR HUMAN FACTORS, MANPOWER, PERSONNEL AND TRAINING ISSUES IN MILITARY SYSTEM DEVELOPMENT

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Research Institute for the Behavioral and Social Sciences

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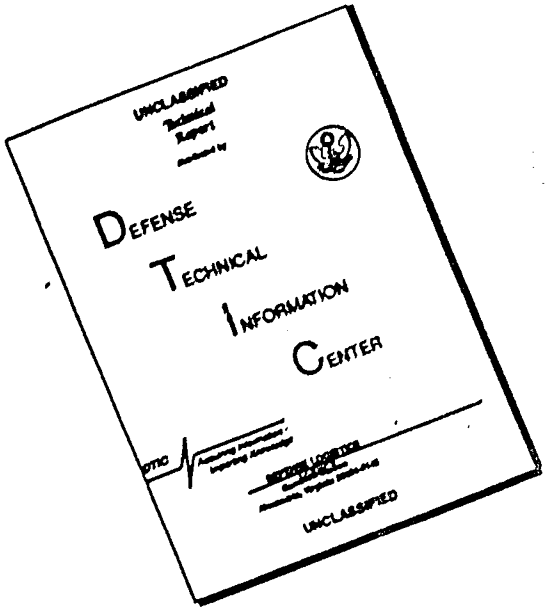

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Life Cycle Cost Analysis
LCCA Methodology
Cost Factors,
System Design,
Subsystem Tradeoffs
Cost Risk/Uncertainity,
Cost Estimating Techniques,

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

These instructional materials were prepared as part of the requirements for a workshop in life cycle cost analysis (LCCA) for human factors, manpower, personnel and training issues in system development. Specific topics covered include: human factors considerations in military systems development, the basic concept and theory of LCCA, the decision and application setting in government and industry, LCCA methodology and fundamental considerations, the cost modeling and estimating process, and selected case examples of the application of LCCA.

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HUMAN FACTORS AND LIFE CYCLE COST ANALYSIS: CONCEPT, PROCESS, AND APPLICATIONS

Life Cycle Cost Analysis (LCCA) is a technique used in resource allocation decisions. It calls for the explicit treatment of all relevant costs incurred over the life of the item or capability under consideration. These costs, or selected cost increments, when coupled with an appropriate effectiveness measure, are the fundamental components of LCCA. The LCCA approach provides a systematic treatment of the full set of relevant costs when considering the development, production, and ownership of a product. Analysts, engineers, managers in government and industry concerned with system procurement, production, operations and support, and program management are finding it necessary to utilize the LCCA concept and technique in their work.

The principal objectives of this course are to provide the participants with a working knowledge of:

(a) Life cycle cost analysis

(b) A rationale for human factors considerations in systems development with specific analyses of human factors principal products at the major development milestones, and other system specific efforts and technological base issues

(c) A multi-step impact assessment framework for formally measuring and relating human factors contributions to military systems life cycle cost management, capability, and compatibility.

Specific topics to be discussed include: human factors considerations in military systems development, the basic concept and theory of LCCA, the decision and application setting in government and industry, LCCA methodology and fundamental considerations, the cost modeling and estimating process, selected case examples of the application of LCCA, and a workshop demonstrating human factors and system life cycle cost design trade-offs.

SUB-SET #1

REVIEW OF HUMAN FACTORS CONTRIBUTIONS DURING THE SYSTEM DEVELOPMENT PHASE

(Note: The structure of the procurement process as presented predates the Carlucci initiative but the basic logic of the sequence remains valid.)

A basic proposition of this course is that, in the context of military systems, both cost and effectiveness are strongly linked to human factors. More specifically, design decisions that neglect the human factors implications are likely to be decisions that contain hidden consequences in the matter of costs as well as in the matter of performance effectiveness. It is not just that, for example, a determination of crew size and composition can serve to drive cost outcomes but that a decision about the physical location of an electronic sub-assembly that does not take into account accessibility can have long-run cost implications because of that neglect.

In this course we will:

- present useful principles and guidelines for the analysis of human factors impacts on military system life cycle costs
  - When to use Life Cycle Cost Analysis (LCCA)
  - Who should use LCCA
- provide a basic methodology for LCCA
  - What the LCCA process is
- review and illustrate useful techniques to estimate costs in the context of LCCA
  - How to estimate LCC

Topical Outline and Course Schedule

I. Introduction

1. Course Focus and Objectives
2. Human Factors, Manpower, Personnel and Training Issues

II. Life Cycle Cost Analysis (LCCA): Why, What, and How

3. Background and Theory
4. Methodology: LCCA Framework

III. Life Cycle Cost Analysis: Important Considerations

5. Cost Estimating Techniques and Effectiveness Measures
6. Factors That Drive Cost and Effectiveness
7. Cost Risk/Uncertainty Analysis
8. Adjusting Cost Estimates

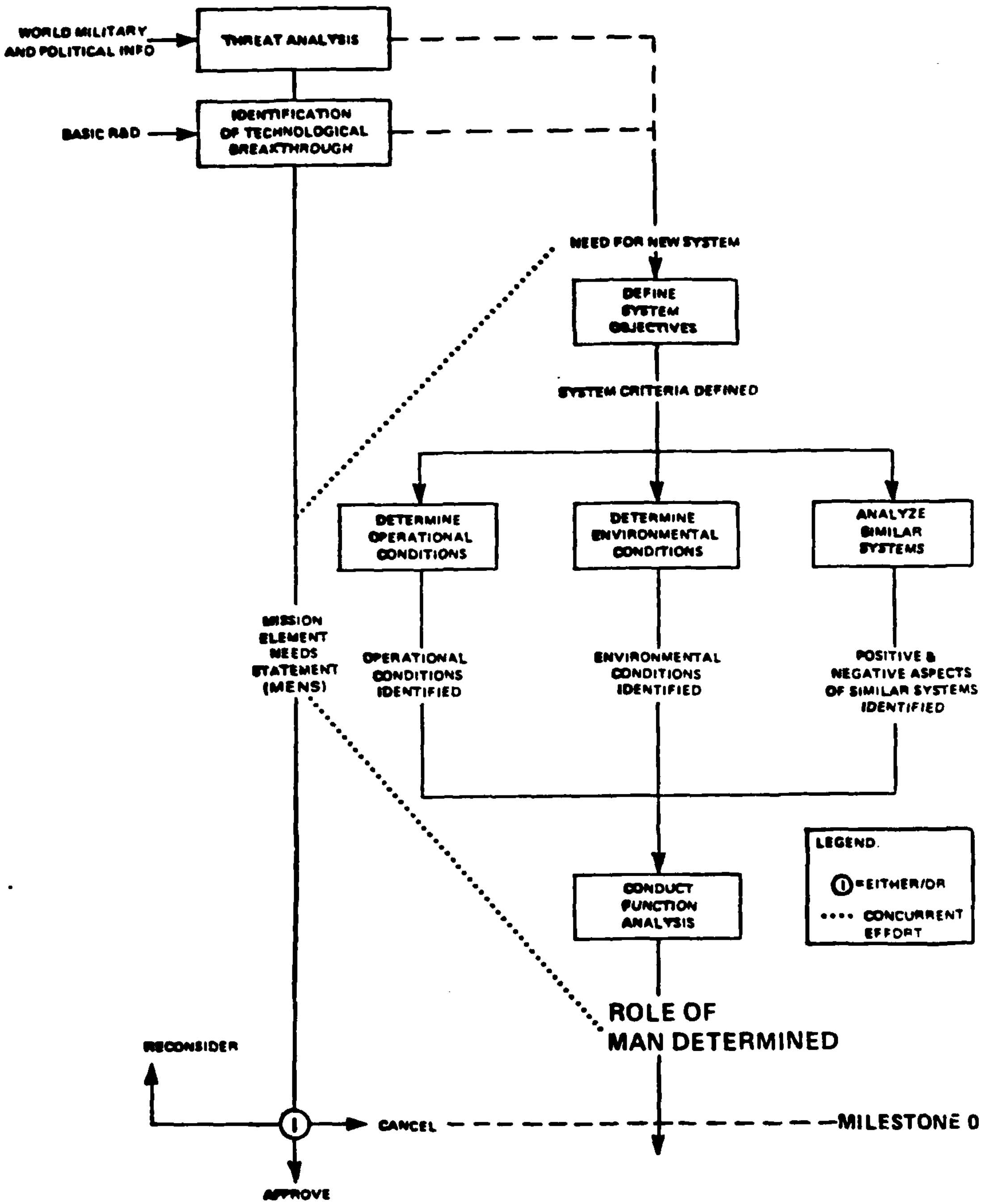
IV. Selected Topics and Applications

9. Economic Analysis: Present Value and Breakeven Analysis
10. Improving the System Design
    - 10.1 Design-to-Cost
    - 10.2 Subsystem Tradeoffs

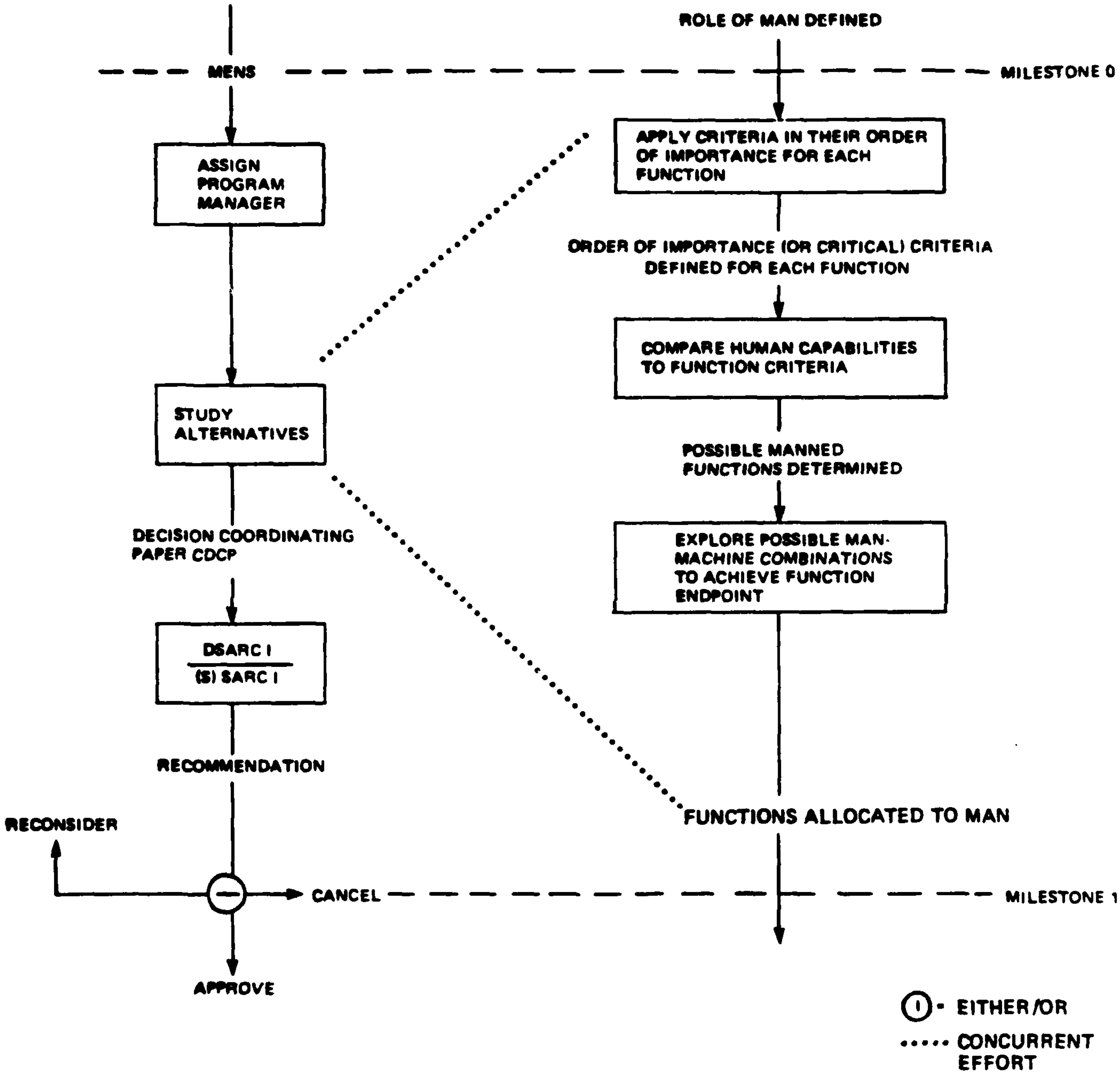
V. Workshop

11. Introduction to the Defense Material System Life Cycle Cost Model
12. Selected Army Systems LCC Analyses

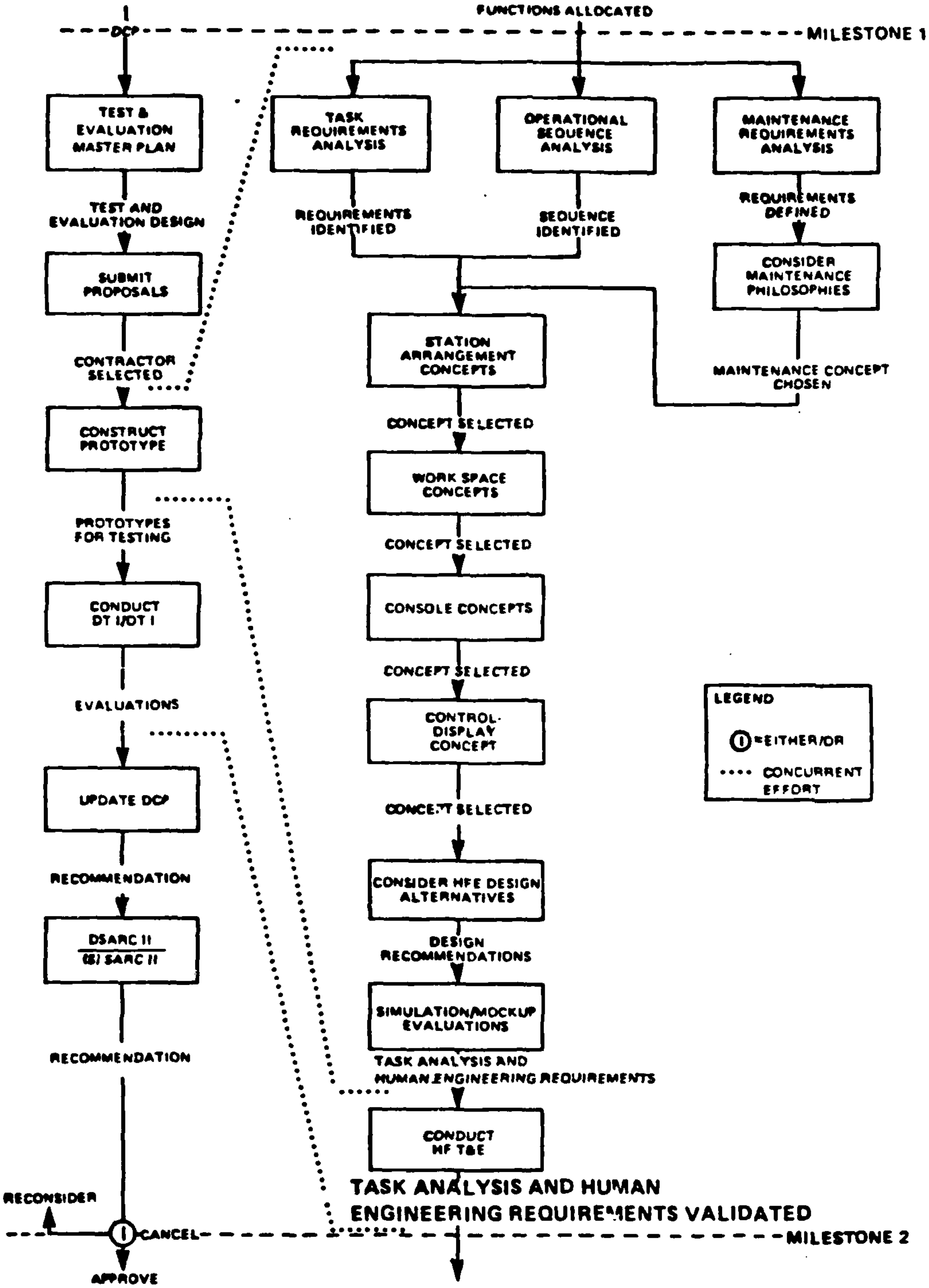
Specific Human Factors Efforts and Products for Each Military System Development Phase



SPECIFIC HUMAN FACTORS EFFORTS AND PRODUCTS FOR EACH MILITARY SYSTEM DEVELOPMENT PHASE



Specific Human Factors Efforts and Products for Each Military System Development Phase



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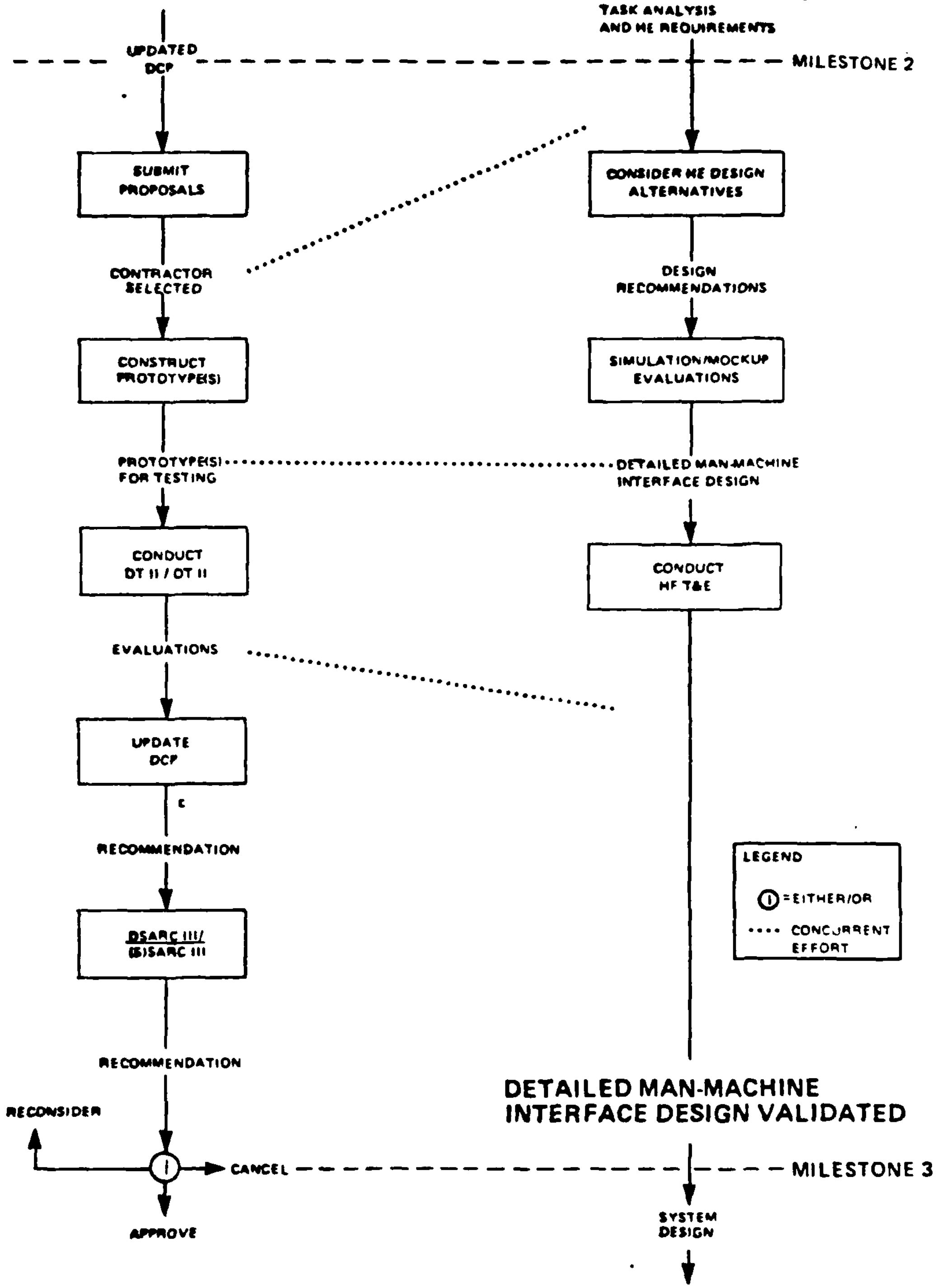
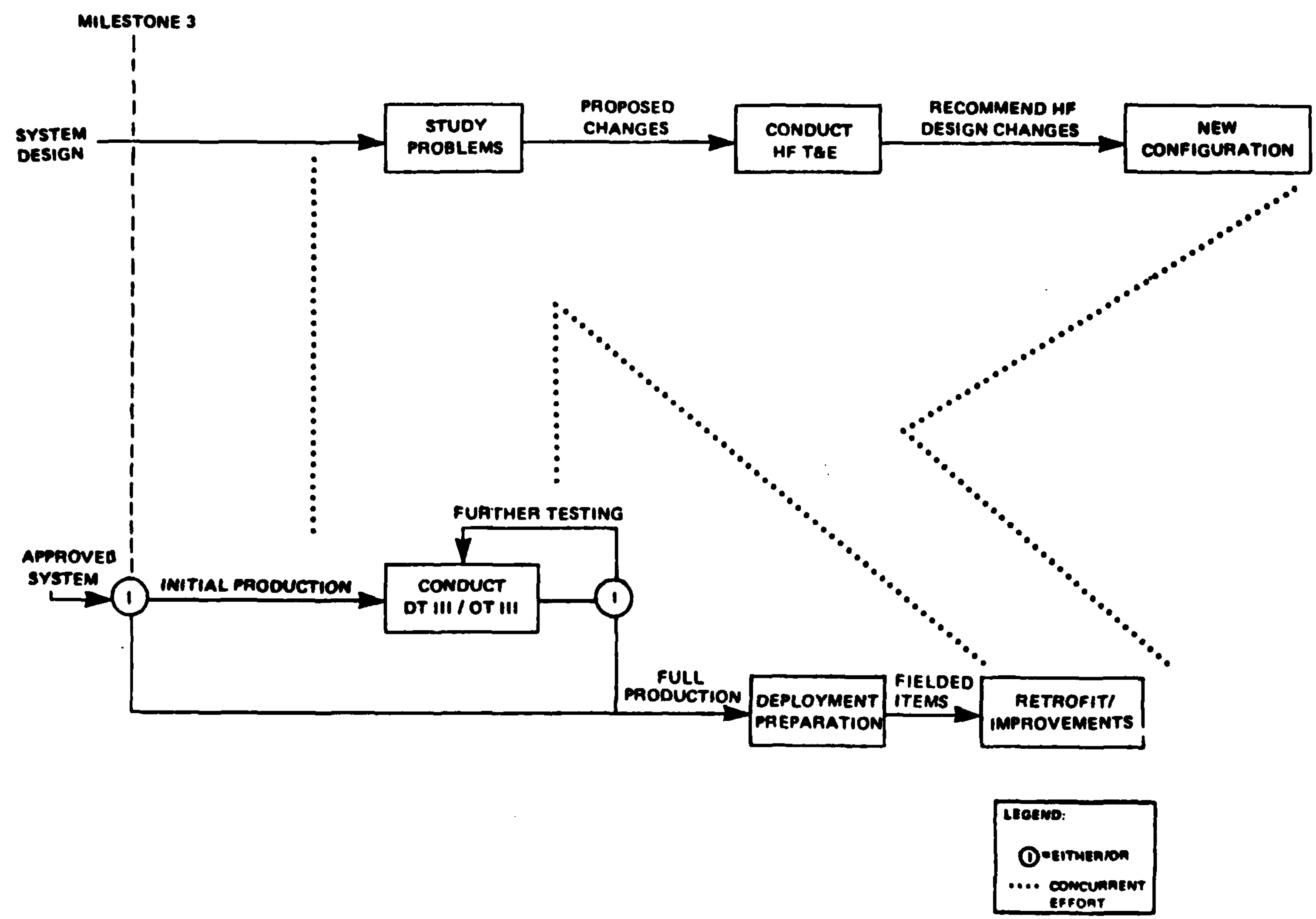


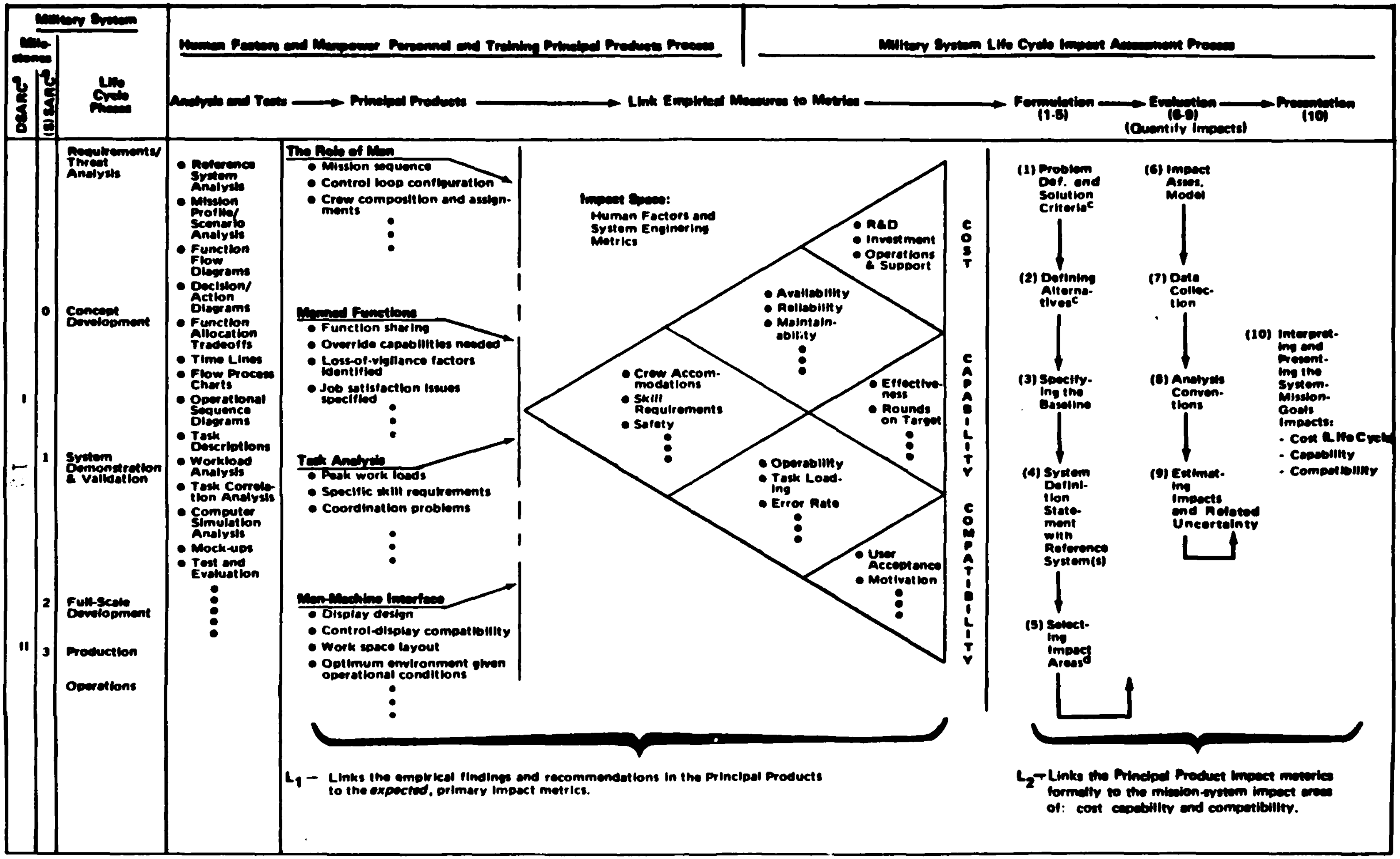
Specific Human Factors Efforts and Products for Each Military System Development Phase



SUB-SET #2

OVERALL RELATIONSHIP BETWEEN HUMAN FACTORS INPUTS AND OUTPUT CRITERIA

Linking Human Factor Changes to System-Mission Impact Areas



[a]As per FY 82 plan for OSD review of major system acquisitions.
[b]As per historical review requirements in a m jor systems' acquisition process.
[c]Derived directly from Human Factors Principal Products.
[d]Derived directly from the impact space and the Principal Product.

SUB-SET #3

MORE EXPLICIT LINKAGES BETWEEN HUMAN FACTORS AND THE COST CRITERION

OVERVIEW OF APPROACH

PRINCIPAL HUMAN FACTOR PRODUCT

IMPACT ANALYSIS METHODOLOGY

MILITARY SYSTEM LIFE CYCLE PHASES → HUMAN FACTOR ANALYSES AND TESTS (INPUT COST ELEMENTS) → LINKING EMPIRICAL MEASURE TO HUMAN FACTOR-SYSTEM ENGINEER IMPACT SPACE —I.E., OPERATIONAL CRITERIA & COSTS → FORMAL QUANTIFICATION OF HUMAN FACTOR IMPACTS (OUTPUT COST CONSEQUENCES VIA SOME INTEGRATIVE PROCEDURE SUCH AS LCCA)

THE EXISTING BASIS FOR HUMAN FACTORS IN SYSTEM DEVELOPMENT

- CIRCULAR A-109
- DOD REQUIREMENTS
  DOD DIRECTIVES 5000.1, 5000.2, AND 5000.3
  MIL-H-46855B
  MIL-STD-1472B
- SERVICE REQUIREMENTS
  ARMY—AR 602-1
  NAVY—NAVMATINST 3900.9
  AIR FORCE—AFR 800-15

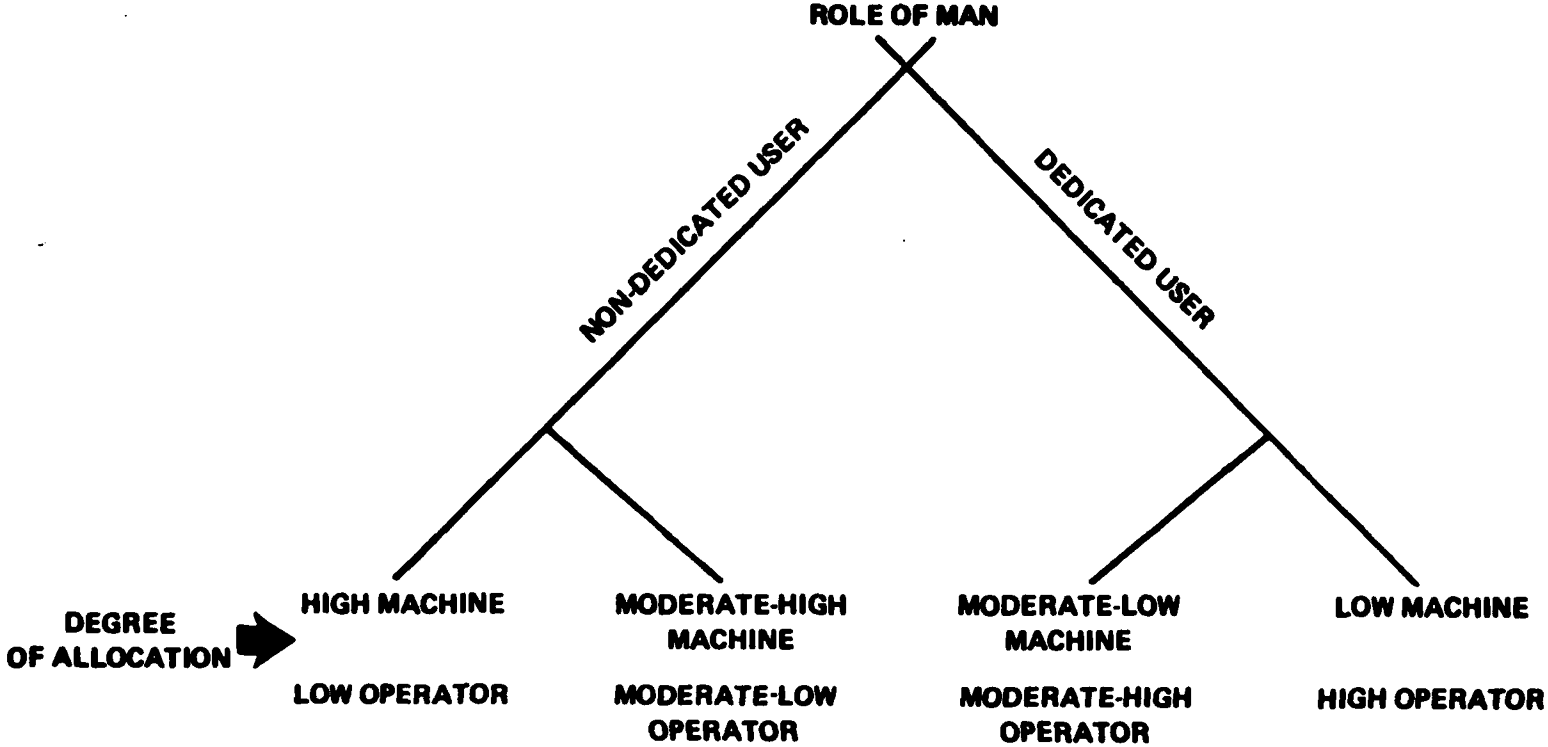
CONCLUSION: THE DOD AND SERVICE REQUIREMENTS PROVIDE FOR HUMAN FACTORS R&D AT ALL LEVELS

PRINCIPAL HUMAN FACTORS PRODUCTS FOR MAJOR SYSTEM DEVELOPMENT PHASES

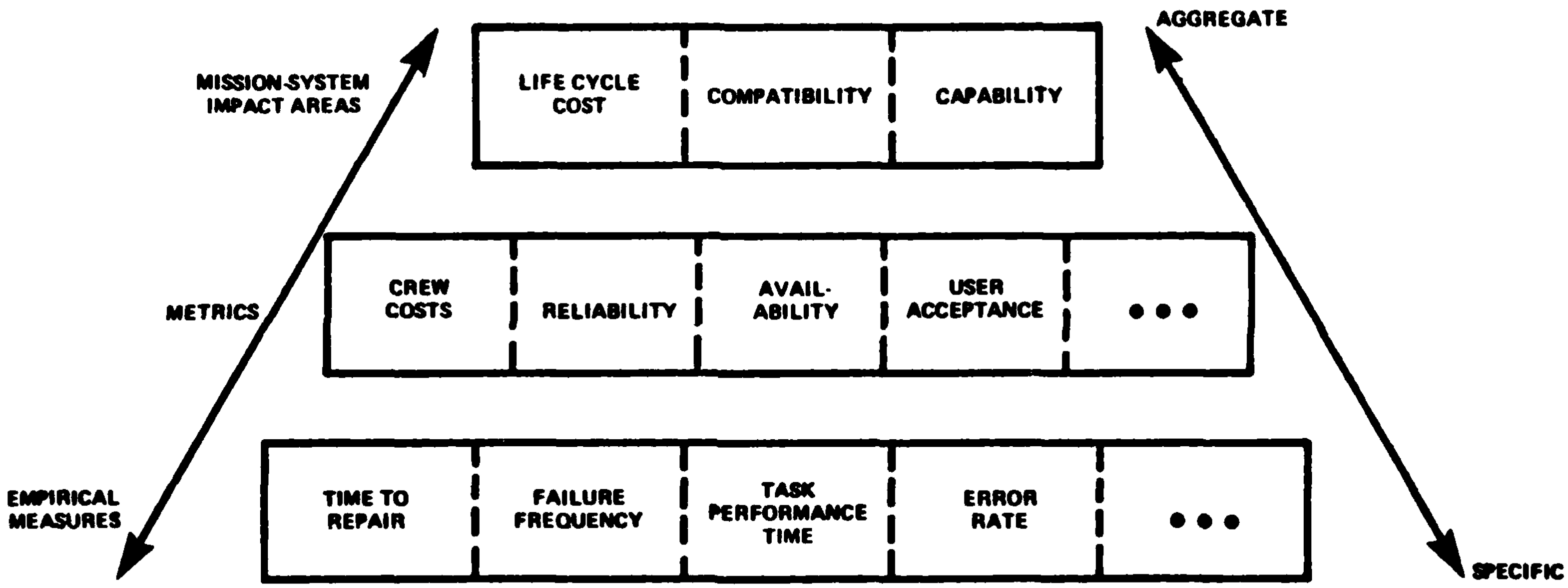
MAJOR PHASE OF SYSTEM ACQUISITION	PRINCIPAL HUMAN FACTOR R&D PRODUCT
MISSION ANALYSIS PHASE	– DEVELOPMENT OF THE ROLE OF MAN ● MISSION SEQUENCE ● CONTROL LOOP CONFIGURATION ● CREW COMPOSITION AND ASSIGNMENTS
CONCEPT DEVELOPMENT PHASE	– ALLOCATION OF SYSTEM MISSION FUNCTIONS TO MAN ● FUNCTION SHARING ● OVERRIDE CAPABILITIES NEEDED ● LOSS-OF-VIGILANCE FACTORS IDENTIFIED ● JOB SATISFACTION ISSUES SPECIFIED
DEMONSTRATION/VALIDATION PHASE	– TASK ANALYSIS AND DETERMINATION OF HUMAN ENGINEERING REQUIREMENTS ● PEAK WORK LOADS ● SPECIFIC SKILL REQUIREMENTS ● COORDINATION PROBLEMS
FULL-SCALE DEVELOPMENT PHASE	– DESIGN OF THE OPTIMAL MAN-MACHINE INTERFACES ● DISPLAY DESIGN ● CONTROL-DISPLAY COMPATIBILITY ● WORK SPACE LAYOUT ● OPTIMUM ENVIRONMENT GIVEN OPERATIONAL CONDITIONS

DEGREE OF FUNCTIONS ALLOCATIONS TO MAN AND MACHINE AS CONSEQUENCE OF ROLE DETERMINATION

AN EXAMPLE OF THE CONCEPTUAL FRAME FOR THE ROLE OF MAN PRODUCT IN THE DEVELOPMENT OF A COMPUTER-BASED C^3I SYSTEM



HIERARCHICAL RELATIONSHIP OF IMPACT AREAS, METRICS, AND EMPIRICAL MEASURES



MEASUREMENT OF HUMAN FACTORS CONTRIBUTION TRIAD OF CRITERIA OR IMPACT AREAS

COST IMPACT AREA

The total relevant, variable cost associated with the system mission over its life cycle.

- Research and Development
- Acquisition Investment
- Operating and Support

CAPABILITY IMPACT AREA

The ability of the system to successfully perform its mission.

- Availability
- Readiness
- Effectiveness

. . .

COMPATIBILITY IMPACT AREA

The overall compatibility of the system design with its operators and maintainers.

- Physical
- Physiological
- Psychological
  - Behavioral
  - Attitudinal

THE RELATIONSHIP OF HUMAN FACTORS ENGINEERING TO MANPOWER, PERSONNEL, AND TRAINING IS ONE OF MUTUAL FACILITATION

- Good Human Factors Engineering Work Can --
  - Reduce of hold down systems manning requirements
  - Minimize crew attrition due to accidents or enemy actions
  - Increase retention by improved job environments and conditions or work
  - Control the training burden by limiting special skills requirements

- Good M - P - T Planning and Management Can --
  - Permit better exploitation of advanced technologies
  - Reduce constraints on design tradeoffs
  - Control deployment and retrofit costs

INVESTMENT COSTS vs OUTCOME SAVINGS - I

SOURCES OF COST GENERATION

- Salary of contract costs of qualified participant(s)
- Recommended design options can be more expensive
- Resolving tradeoff questions uses time or other team members.

POTENTIAL LIFE-CYCLE COST SAVINGS

- Reduced likelihood of system failure at operational test stage
- Reduced likelihood of user rejection -- overt or covert
- Reduced likelihood of costly retrofit

INVESTMENT COSTS vs OUTCOME SAVINGS -- II

- Investment Costs Are:
  - Immediate
  - Visible
  - Certain
- Outcome Savings Are:
  - Delayed
  - Often Intangible
  - Probablistic

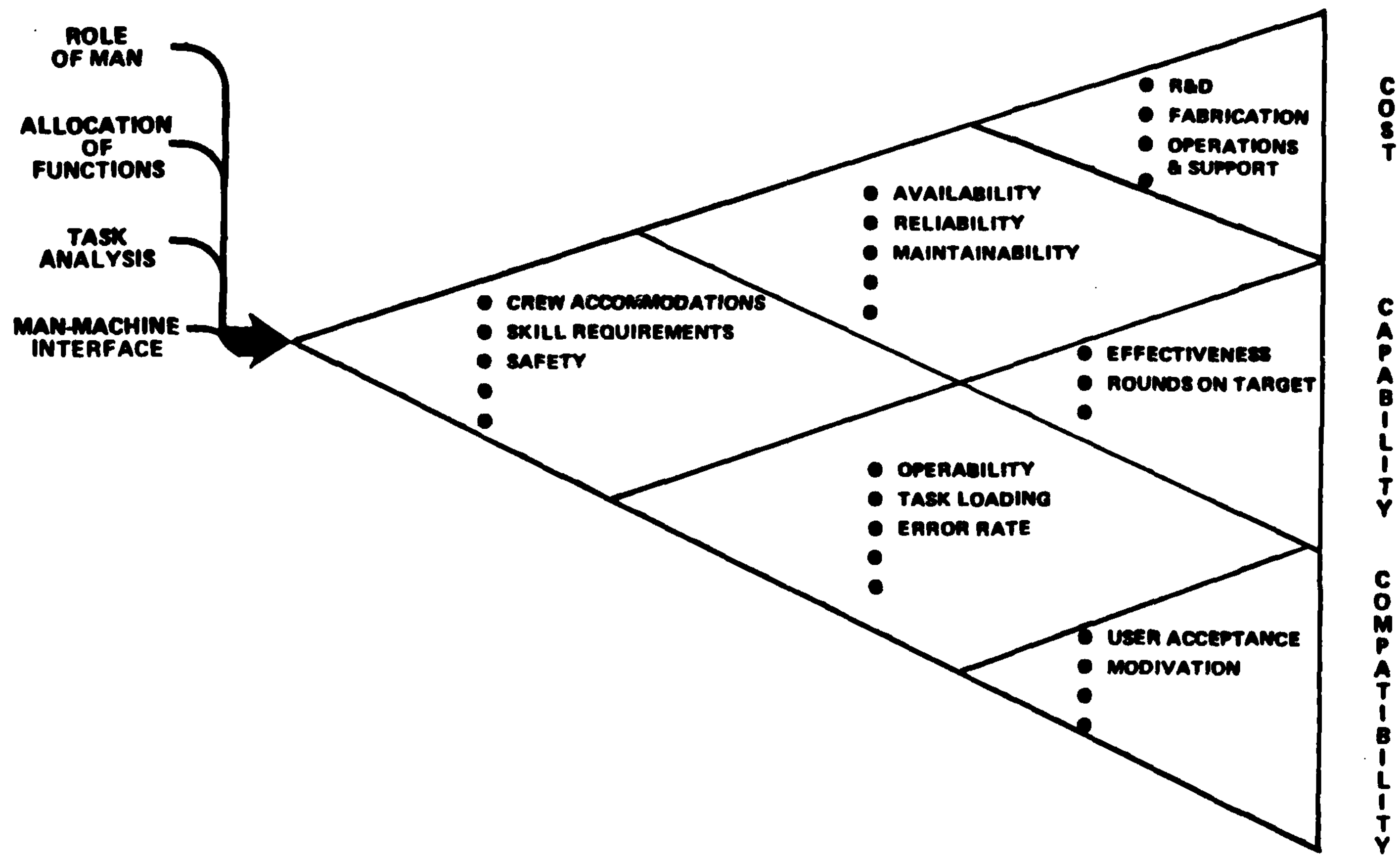
INVESTMENT COSTS vs OUTCOME SAVINGS - III

HUMAN FACTORS INPUTS CAN SERVE AS A MANAGERIAL CONTROL MECHANISM

		CONTROLLED	NOT CONTROLLED
LIFE CYCLE COSTS	INCREASED	LIKELY	VERY LIKELY
	DECREASED	POSSIBLE	VERY UNLIKELY*

*DECREASED COSTS -- I.E., SAVINGS -- ARE VERY UNLIKELY IN THE ABSENSE OF MANAGERIAL CONTROLS

IMPACT SPACE: LINKS BETWEEN HUMAN FACTORS AND SYSTEM ENGINEERING



SUB-SET #4

SPECIFIC RELATIONSHIP BETWEEN HUMAN FACTORS AND LCCA

WHAT ARE THE BASIC PROBLEMS/DECISIONS LCCA CAN HELP ANALYZE ?

- Unanticipated cost escalation during either development or operational phases
- Missed opportunities to preclude large future expenditures by small current investments
- Missed opportunities to achieve significant effectiveness enhancements at low cost

d. Management of cost and effectiveness risks

What is the BASIC APPROACH used in LCCA to solve such problems?

a. Formal, disciplined delineation of all source factors

b. The integration of cost source factors in a quantitative project model

c. Successive update of conclusions/recommendations by periodic recalculations using empirical data as these become available over time

What are the PROBLEMS that HFE/MPT work is intended to address?

- Human-system is compatabilities that result in system performance degration or use-cost escalation or both.

- Lack of availability of adequately skilled personnel to operate/maintain the system when it is ready for deployment

What is the basic APPROACH used in HFE/MPT to confront (resolve or ameliorate) such problems ?

- Performance requirements analyses at system and crew-position levels.

- Comparison of performance requirements against human capabilities/limitations

- Reconciling requirements to capabilities by:
  - downgrading requirements by design
  - upgrading capabilities by selection, training, or assignment/allocation

In What Respects are the Two Activity Areas, LCCA and HFE/MPT Interconnected?

- Conceptually -- concurrance on objective of maximizing performance and minimizing net costs.
- Conceptually -- common roots in general system theory; systems engineering vocabulary.
- Methodologically -- common reliance on analytical models for outcome projections.
- Methodologically -- sharing of similar technical problems of measurement (e.g., scaling, quantification of intangibles) and utilization of statistics in matters such as comparative evaluation of alternatives -- trade-off techniques, etc.

SUB-SET #5

INTRODUCTION TO LCCA

LIFE CYCLE COST ANALYSIS: WHY, WHAT AND HOW

- <u>BACKGROUND AND THEORY</u>

LCCA -- HOW IS IT USED?

- A COST ANALYSIS DISCIPLINE
- A PROCUREMENT POLICY
- ACQUISITION CONTRACTURAL COMMITMENTS
- TOOL FOR PRODUCT IMPROVEMENT TRADE-OFFS "COURSE FOCUS"
- MANAGEMENT/PLANNING STRATEGY FOR LONG-TERM INVESTMENTS

THE GENERAL CONCEPT OF LIFE CYCLE COST ANALYSIS

A TECHNIQUE USED IN RESOURCE ALLOCATION DECISIONS CONCERNING SYSTEM DESIGN, ACQUISITION AND CONTROL THAT FOCUSES ON THE TOTAL RELEVANT LIFE-TIME COSTS OF THE SYSTEM AND ITS EXPECTED EFFECTIVENESS.

WHY IS LCCA IMPORTANT FOR MANAGERS IN BOTH GOVERNMENT AND INDUSTRY?

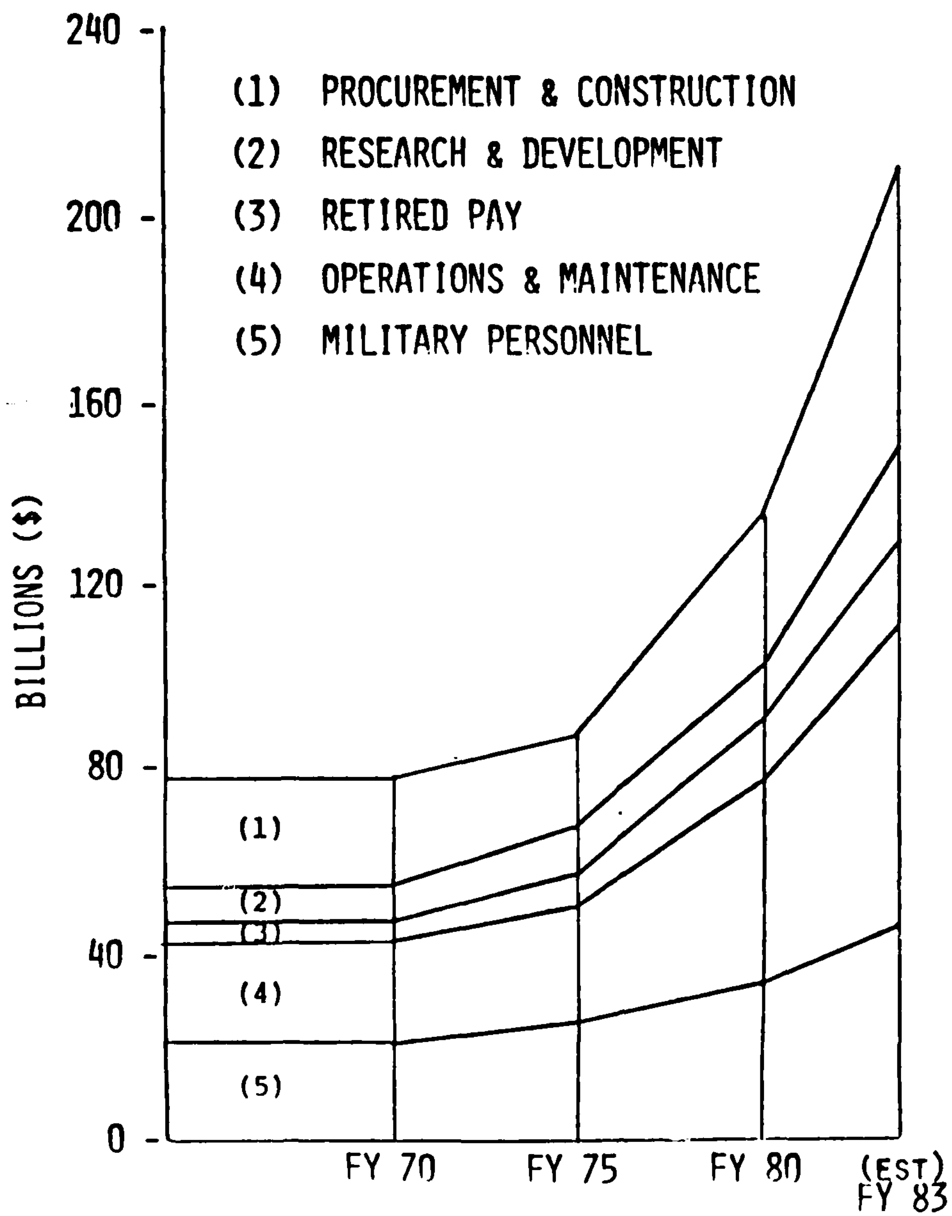
- IDENTIFIES THE RELEVANT RESOURCE IMPACT REQUIREMENTS OF A PROPOSAL
- FACILITATES THE PROCESS OF ANALYSIS
- PROVIDES A BASIS FOR THE MANAGEMENT OF SYSTEM LCC
- A FORMAL PROCESS TO INFLUENCE SYSTEM DESIGN
- CONTRIBUTES TO THE ESTABLISHMENT OF A PREFERRED COMPETITIVE ENVIRONMENT
- PROVIDES A CONSISTENT BASIS FOR BUDGET IMPACT ANALYSIS
- TREATS LCC AS AN EXPLICIT DECISION PARAMETER ALONG WITH PERFORMANCE AND TIME

WHAT ARE THE BENEFITS OF LCCA

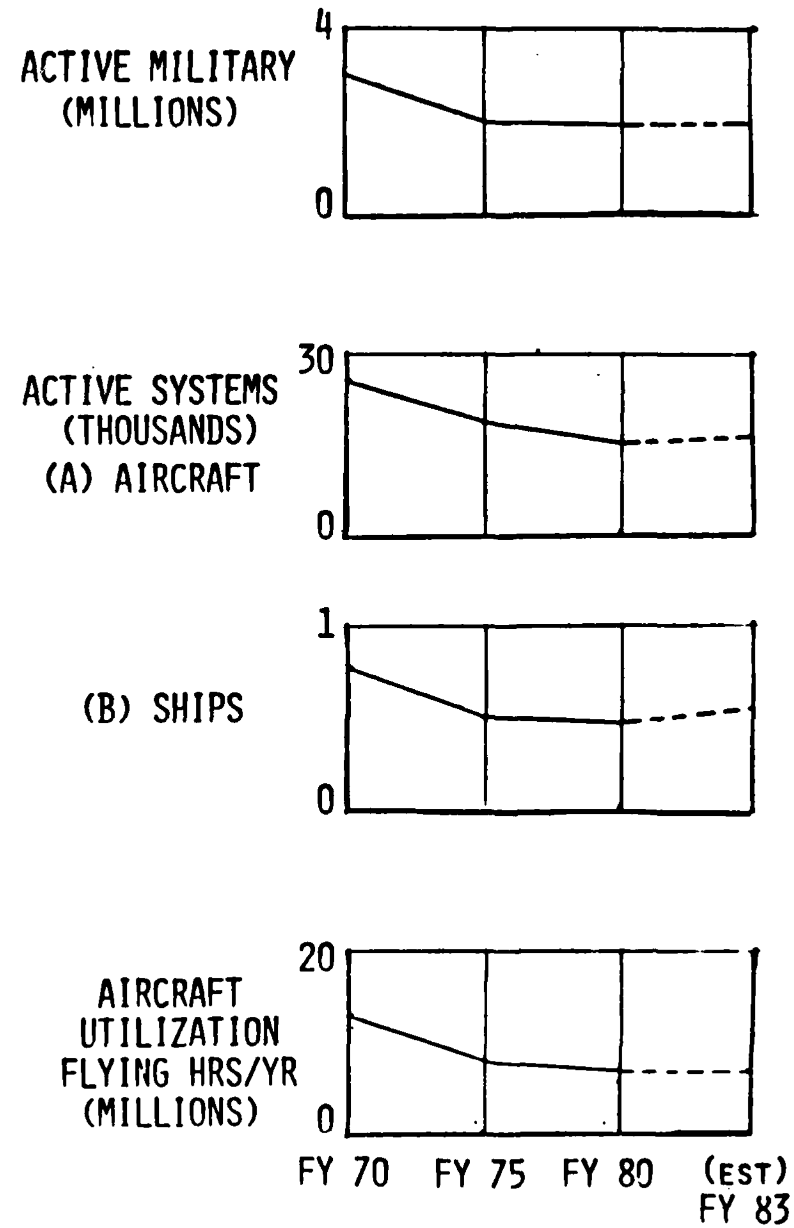
- SIGNIFICANT SAVINGS
- BALANCE ACQUISITION AND OPERATING BUDGETS
- IMPROVED MANAGEMENT OF HIGH LEVERAGE ISSUES
  - CONCEPTUAL DESIGN (80:20)
- MORE COST EFFECTIVE SYSTEMS

THE BASIC COST ISSUE

DEFENSE OUTLAYS
(UNADJUSTED - CURRENT YEAR DOLLARS)



SIGNIFICANT TRENDS



SIGNIFICANCE OF OPERATING AND SUPPORT (O&S) COSTS

(UNADJUSTED - BASE YEAR CONSTANT DOLLARS)

(MILLIONS OF DOLLARS)

	A-7D	A-10	M-1	FFG
UNIT-ACQUISITION COST[1]	4.2	3.5	.7	50
UNIT-O&S COSTS[2]	8.7	7.8	2.2	150
LCC	12.9	11.3	2.9	200

---

1 INCLUDES R&D AND PROCUREMENT

2 INCLUDES ONLY DIRECT O&S COSTS AND OTHER BATTALION OR SQUADRON LEVEL SUPPORT; AND ASSUMES THE FOLLOWING OPERATIONAL LIFE:

TANK	(M-1)	- - 10 YEARS
AIRCRAFT	(A-7D, A-10)	- - 15 YEARS
SHIP	(FFG)	- - 30 YEARS

TYPICAL DISTRIBUTION OF LIFE CYCLE COSTS

(Defense Systems)

System Type	Acquisition	Operations & Support
Aircraft (Fighter)	30 - 50%	50 - 70%
Combat Vehicles	20 - 30%	70 - 80%
Ships (Destroyers)	25 - 40%	60 - 75%

(Based on Unadjusted Costs)

TYPICAL LCCA COST CATEGORIES

(DEFENSE SYSTEMS)

LCC EQUALS THE SUM OF:

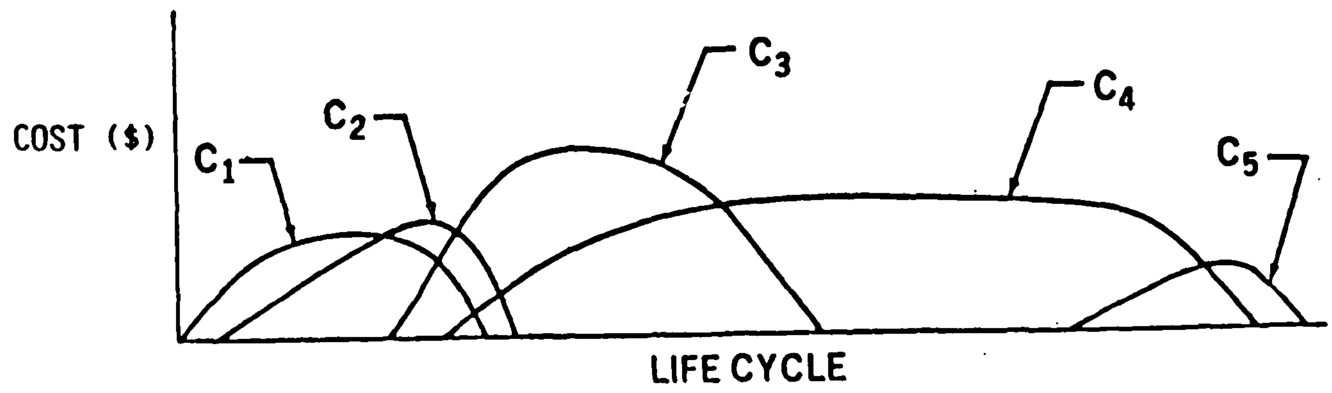
C_1 = RESEARCH AND DEVELOPMENT

\+ C_2 = TEST AND EVALUATION

\+ C_3 = INVESTMENT (PRODUCTION)

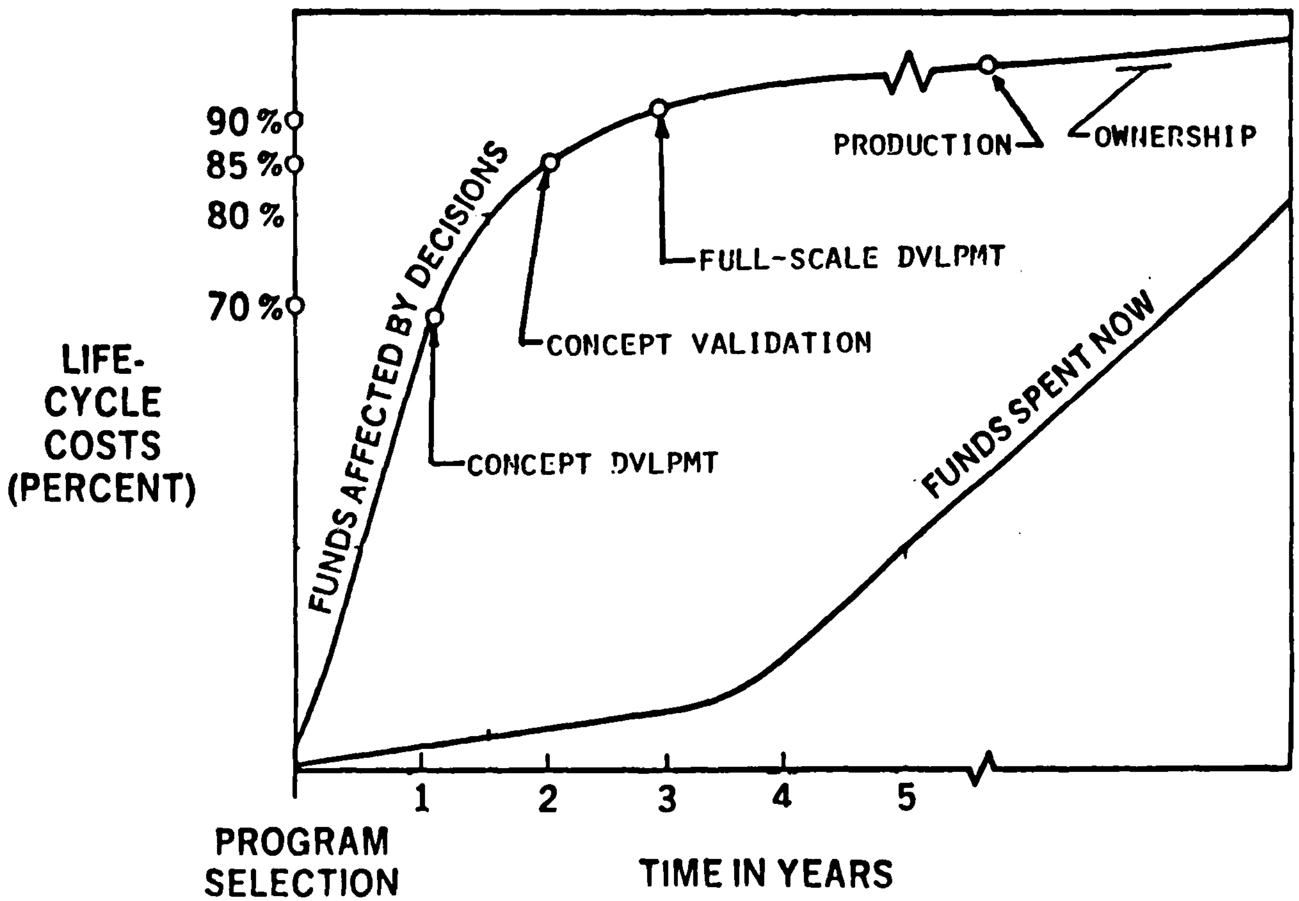
\+ C_4 = OPERATING AND SUPPORT

\+ C_5 = DISPOSAL



TYPICAL · MILESTONES AND RELATED COMMITMENTS

(DEFENSE SYSTEMS)

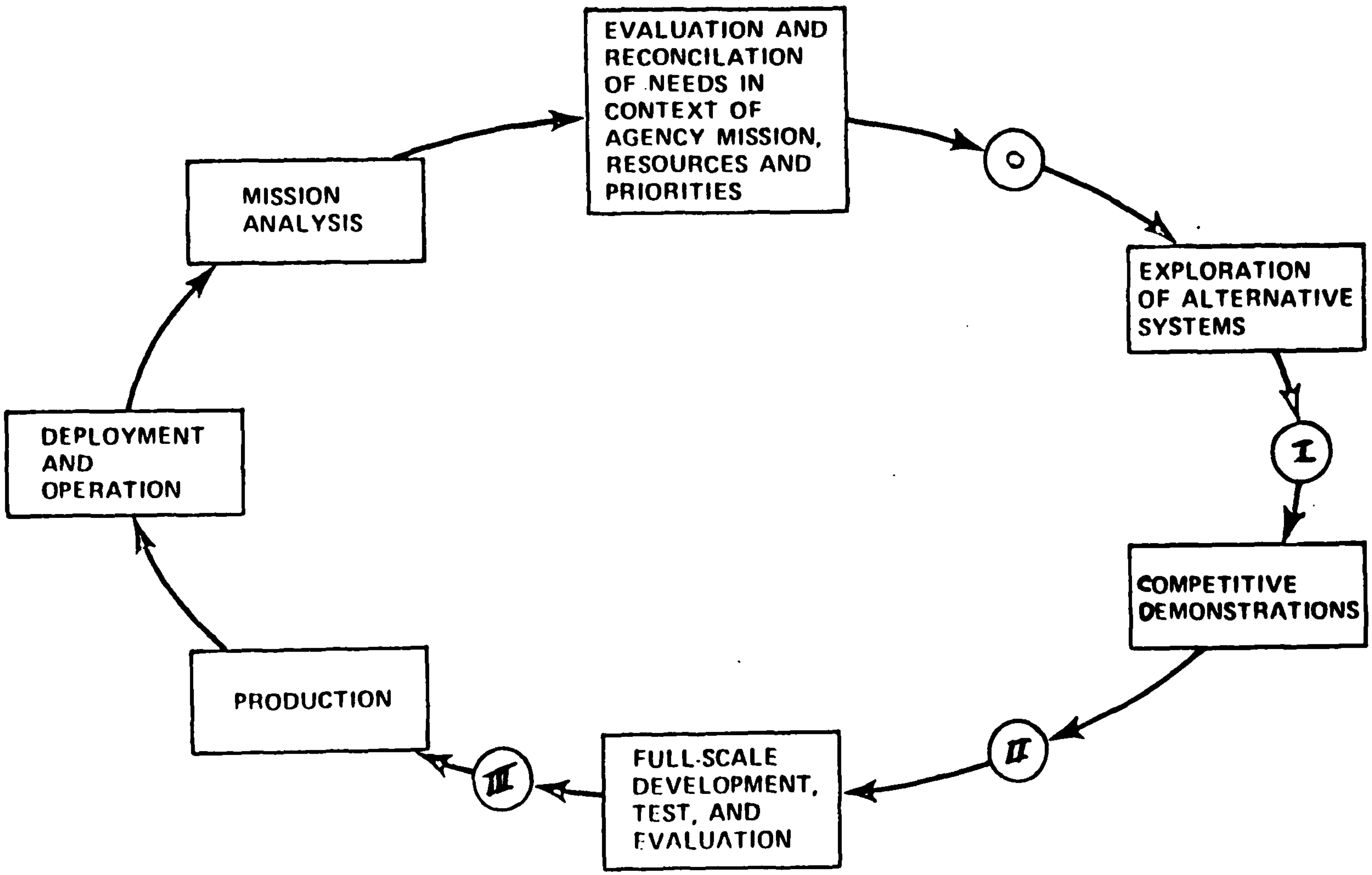


THE SYSTEM ACQUISITION PROCESS

AND

DOD'S LIFE CYCLE COST REQUIREMENTS

MAJOR SYSTEM ACQUISITION CYCLE*



SOURCE: OFPP PAMPHLET NO 1, MAJOR SYSTEM ACQUISITIONS

OBJECTIVES OF OMB CIR. A-109

- MISSION RELEVANCE AND EFFECTIVENESS
- REDUCE COSTS THROUGH - BENEFICIAL COMPETITION
  - APPROPRIATE LIFE CYCLE COST TRADEOFFS
- ADEQUATE SYSTEM TEST AND EVALUATION
- TAILORED ACQUISITION STRATEGIES
- EFFECTIVE LIFE CYCLE COST EVALUATION AND CONTROL

MAJOR SYSTEM ACQUISITION KEY DOCUMENTS

A-109	FEDERAL PROCUREMENT POLICY
DODD 5000.1	DEFINES "MAJOR" SYSTEMS, ESTABLISHES MILESTONES, AND DEFENSE SYSTEM ACQUISITION REVIEW COUNCIL (DSARC) POLICY
DODI 5000.2	DEFINES THE MAJOR SYSTEM ACQUISITION PROCESS, DECISION COORDINATING PAPER (DCP), MISSION ELEMENT NEEDS STATEMENT (MENS), INTEGRATED PROGRAM SUMMARY (IPS)
DODD 5000.3	ESTABLISHES THE TEST AND EVALUATION PROCESS
DODD 5000.4	ESTABLISHES THE INDEPENDENT PARAMETRIC COST REVIEW PROCESS AND THE CAIG
DODD 5000.28	DEFINES DESIGN TO COST POLICY
DODD 5000.30	ESTABLISHES THE DEFENSE ACQUISITION EXECUTIVE (DAE)
DODD 7920.1	ESTABLISHES POLICY FOR LIFE CYCLE MANAGEMENT OF AUTOMATED INFORMATION SYSTEMS (AIS)
DODI 7920.2	DEFINES AUTOMATED INFORMATION SYSTEM APPROVAL PROCESS
⋮	

(SEE REFERENCE SECTION FOR COMPLETE LIST)

LIFE CYCLE COST

"THE TOTAL COST TO THE GOVERNMENT OF ACQUISITION AND OWNERSHIP OF THAT SYSTEM OVER ITS FULL LIFE. IT INCLUDES THE COST OF DEVELOPMENT, PRODUCTION, OPERATION, SUPPORT, AND WHERE APPLICABLE, DISPOSAL."

DODD 5000.28

OPERATIONS AND SUPPORT COSTS INCLUDE ALL COSTS CHARGED TO THE OPERATIONS AND SUPPORT OF THE WEAPON SYSTEM, INCLUDING THE COST OF MAINTENANCE OF THE SYSTEM ONCE DEPLOYED.

DOD PROGRAM

- GET VISIBILITY OF AND TRACK OPERATING AND SUPPORT (O&S) COSTS
- IDENTIFY OPERATING AND SUPPORT (O&S) COST DRIVERS
- STANDARDIZE O&S COST ELEMENT STRUCTURE
- IDENTIFY O&S-RELATED DESIGN PARAMETERS
- DEVELOP METHODOLOGY TO SUPPORT DOD GOALS
- IMPLEMENT INCENTIVES FOR REDUCING O&S COSTS
- ESTABLISH DESIGN TO COST AND LIFE CYCLE COST TARGETS AND THRESHOLDS
- RELATE READINESS AND LIFE CYCLE COST
- ESTABLISH AND MONITOR INTEGRATED PROGRAM SUMMARY (IPS)
- REQUIRE REALISTIC (MOST-LIKELY) COST ESTIMATES
- EFFECTIVE SYSTEM MANNING

ITEMS PURCHASED BY THE GOVERNMENT
IN WHICH LIFE CYCLE COSTS WERE UTILIZED

(SAMPLE)

SOILD STATE REGULATORS
HYDRAULIC SERVO CYLINDERS
RADIO FILTERS
TACHOMETER INDICATOR
STORAGE BATTERIES
AIRCRAFT TIRES
TRAVELING WAVE TUBES
OSCILLOSCOPES
MAIN LANDING GEAR
UHF COMMAND RADIO
POWER SUPPLY
CARGO DOOR ASSEMBLY
REFUELING BOOM

TACHOMETER GENERATORS
ELECTRON TUBES
GYROSCOPES
DIESEL ENGINES
NOSE LANDING GEAR
INERTIAL NAVIGATION SYSTEM
PULSE TRANSFORMERS
GEAR CASE MOTOR
ENGINE STARTER
CUNSTANT SPEED DRIVERS
ENGINE EXHAUST CONE
ABSOLUTE ALTIMETER (AN/APN-209)
AIRCRAFT PUMP (F-14 AIRCRAFT)

DEFENSE SYSTEMS/SUBSYSTEMS IN WHICH LIFE CYCLE COSTS WERE UTILIZED (SAMPLE)

SAM-D AIR DEFENSE SYSTEM

LIGHT HELICOPTER ASSAULT SHIP (LHA)

CONUS OVER THE HORIZON RADAR (414-L)

AEGIS

A-10, F-16, F-18 AIRCRAFT

UHF MODERNIZATION RADIO PROGRAM (ARC-XX)

UNDERGRADUATE PILOT TRAINING INSTRUMENT FLIGHT SIMULATOR

B-1 AIRCRAFT

AIR FORCE SATELLITE CONTROL FACILITY EQUIPMENT

LORAN (AN/ARN-101)

POSITION APPROACH RADAR (GPN-XX)

AIRBORNE TACAN SETS (ARN-XX)

DEFENSE NAVIGATION SATELLITE DEVELOPMENT PROGRAM

MULTI-MODE MATRIX DISPLAY ADVANCED DEVELOPMENT PROGRAM

ADPE ACQUISITIONS (7 DIFFERENT PROG.)

GENERAL PURPOSE 5 TON VEHICLE

CAS GUN (GAU-8)

NAVY PATROL FRIGATE, HYDROFOIL SHIP

ADVANCED ATTACK HELICOPTER

MANPADS (A) (STINGER)

HARPOON

LIGHTWEIGHT FIGHTER

AIM-7F MISSLE

SEA CONTROL SHIP

SUBMARINE SONAR (AN-BQQ-5)

NEW MAIN BATTLE TANK (MBT)

AWACS

INSTRUMENT LANDING SYSTEM (ILS)

LOW COST EW SUITE

SAFEGUARD SYSTEM

COBRA DANE

PAVE PAWS

THE DECISION SETTING: LCCA OBJECTIVES

1. TO COMPARE AND SELECT THE PREFERRED ALTERNATIVE

   A) LCCA AS A DISCIPLINE:

   - STANDARDIZATION; VISIBILITY TO TOTAL COSTS TO BE CONSIDERED; DEFINITION AND SELECTION OF COST ELEMENTS AND THEIR COMPUTATION

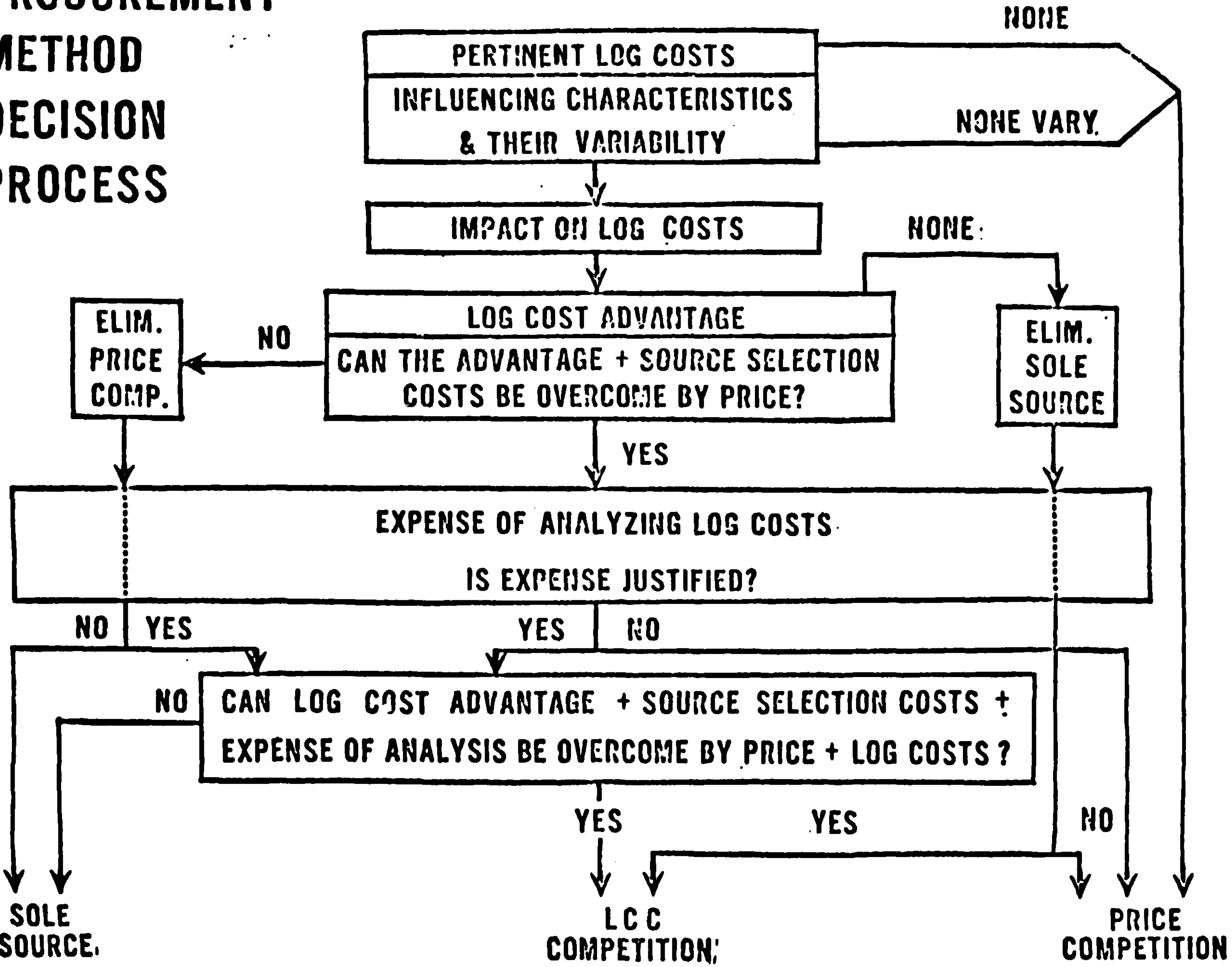
   B) LCCA AS A PROCUREMENT TECHNIQUE:

   - MINIMUM COST PER USAGE APPLICATION
   - SOURCE SELECTION CRITERION

   C) LCCA AS AN ACQUISITION CONSIDERATION:

   - BALANCE ACQUISITION AND OWNERSHIP COSTS
   - SOURCE SELECTION INFORMATION

PROCUREMENT METHOD DECISION PROCESS



THE DECISION SETTING: LCCA OBJECTIVES
(CONTINUED)

2. TO IMPROVE A GIVEN DESIGN

   A) LCCA AS A DESIGN TRADEOFF TOOL

   - INCORPORATE COST AS A SYSTEM DESIGN PARAMETER
   - TO MINIMIZE LCC AS A DESIGN STRATEGY

THE DECISION SETTING: LCCA OBJECTIVES
(CONTINUED)

3. TO CONTROL A PROCUREMENT PROGRAM

A) LCCA AS A MANAGEMENT FUNCTION AND A CONTROL MECHANISM

- TO MANAGE TO LCC (E.G., DESIGN TO COST)
- LCC MANAGEMENT AND CONTRACT INCENTIVES

THE DECISION SETTING: LCCA OBJECTIVES
(CONTINUED)

4. TO MANAGE AN OPERATIONAL SYSTEM

   A) LCCA AS A MEANS OF DEFINING THE RELEVANT COSTS

   B) LCCA AS A MEANS OF ESTABLISHING A MANAGEMENT FEEDBACK PROCESS

THE DECISION SETTING: LCCA OBJECTIVES
(CONTINUED)

5. TO ENHANCE MANAGEMENT AND PLANNING STRATEGIES FOR LONG-TERM INVESTMENTS

   A) LCCA AS A PART OF MANAGEMENT PLANNING

      - BUDGET IMPACT ANALYSIS
      - ESTIMATING FUTURE BUDGET REQUIREMENTS

   B) LINKING THE LCC ESTIMATE TO THE BUDGET MECHANISM

LCCA - PRINCIPAL FORMULATION

- IDENTIFY THE OPPORTUNITY THAT MAXIMIZES EFFECTIVENESS OVER THE AGGREGATE RELEVANT VAIRABLE COSTS
  - EXPLICIT MEASURES OF EFFECTIVENESS (E)
  - EXPLICIT AGGREGATION OF COSTS (C)
    - UNADJUSTED
    - DISCOUNTED
  - FOR ALL CANDIDATE OPPORTUNITIES (J)

LIFE CYCLE COST ANALYSIS

OBJECTIVE: MAX/MIN F(MEASURE OF EFFECTIVENESS, COST)

$$\text{E.G.,}\quad \max_{J}\left[\frac{\text{MEASURE OF EFFECTIVENESS}}{\sum_{I} \text{DISC. } C_I}\right]$$

SUBJECT TO:
- DECISION AND ORGANIZATIONAL SETTING
- APPLICABILITY AND COST-EFFECTIVENESS OF LCCA
- FEASIBILITY OF APPROACH
- ITEM CHARACTERISTICS

CANDIDATE CONCEPTS OF COST

- FUTURE DOLLAR OUTLAY
  - BUDGET IMPACT/OUTLAY
  - AUDIT PERSPECTIVE
- ECONOMIC COSTS
  - TOTAL WORTH OF RESOURCES CONSUMED
- OPPORTUNITY COSTS
  - THE COSTS OR PENALTY INCURRED WHEN AN OPPORTUNITY IS FORGONE
- RELEVANT VARIABLE COSTS
  - FUTURE COSTS THAT ARE AFFECTED BY A CURRENT DECISION
  - THOSE COSTS THAT VARY AMONG THE ALTERNATIVES UNDER CONSIDERATION
- SUNK OR INHERITED COSTS
  - FIXED (NON-VARIABLE) COSTS
- ADJUSTED VS. NON-ADJUSTED COSTS
  - CURRENT (THEN YEAR) COSTS
  - CONSTANT (BASE YEAR) COSTS
  - DISCOUNTED/INFLATED ADJUSTMENTS

LCCA - THE CONCEPT OF EFFECTIVENESS

- THE OUTPUT OR RESULT OF A SYSTEM OR ACTION
- A MEASURE OF WHAT YOU ARE GETTING
- A METRIC OR SCALE USED TO INDICATE THE DEGREE OF ACHIEVEMENT OF AN OBJECTIVE AND CONTRIBUTION TO A GOAL

DERIVING MEASURES OF EFFECTIVENESS

- REFLECT THE ESSENCE OF THE PROBLEM (MISSION, GOAL, OBJECTIVE)
  - INTRINSIC
  - EXTRINSIC
- IMPORTANT TO THE DECISION UNDER CONSIDERATION
- SIMPLICITY
- MEASUREABLE
- SYSTEMS EMBEDDING

TYPICAL MEASURES OF EFFECTIVENESS

- BASIC DIMENSIONS
  - OUTPUT
  - DURABILITY
  - RELIABILITY
  - PERFORMANCE
  - QUALITY
  - IMPACT

  •
  •
  •

LCCA: TYPICAL MEASURES OF EFFECTIVENESS

"A MEASURE OF WHAT YOU ARE GETTING"

- TIRES - NUMBER OF MILES: NUMBER OF LANDINGS:
- SYSTEM - AVAILABILITY; RANGE;...
- ENGINE - SPECIFIC IMPULSE; HORSEPOWER/WEIGHT;...
- TRANSMISSION - MTBF; TIME BETWEEN OVERHAULS;...
- TRANSPORT VEHICLE - SPEED TIMES CAPACITY;...
- C^3 I -

MEASURES OF EFFECTIVENESS HIERARCHICAL STRUCTURE

COMMUNICATION EQUIPMENT *

SYSTEM EFFECTIVENESS

- COMMUNICATION MEASURES
  - GRADE OF SERVICE
  - INFORMATION QUALITY
  - SPEED OF SERVICE
  - CALL PLACEMENT TIME
  - SERVICE FEATURES
  - LOST MESSAGE RATE
  - SPECTRUM UTILIZATION
- STABILITY MEASURES
  - INDEX OF SURVIVABILITY (OVERT)
  - INDEX OF SURVIVABILITY (JAMMING)
  - INDEX OF AVAILABILITY
  - INTERRUPT RATE
- REORGANIZATION MEASURES
  - TRANSPORTABILITY
  - MOBILITY
  - EASE OF RECONFIGURATION
  - EASE OF TRANSITION
  - INTEROPERABILITY
- SECURITY
  - X
  - Y
  - Z

* TRI TAC LCCA MODEL

SOME SIMPLE EXAMPLES TO ILLUSTRATE:

1. EFFECTIVENESS MEASURES AND REQUIREMENTS
2. OPPORTUNITY COSTS

APPLICATION OF LCCA FOR AUTO TIRES

	PRODUCT A	PRODUCT B
INVESTMENT (UNIT PRICE)	$30	$40
OPERATION AND SUPPORT COST	—	—
EXPECTED MILEAGE*	20,000	30,000
COST PER MILE	0.0015	0.0013

*ASSUMES THAT THE REQUIREMENT EXCEEDS THE OPERATIONAL LIFE OF THE TIRE.

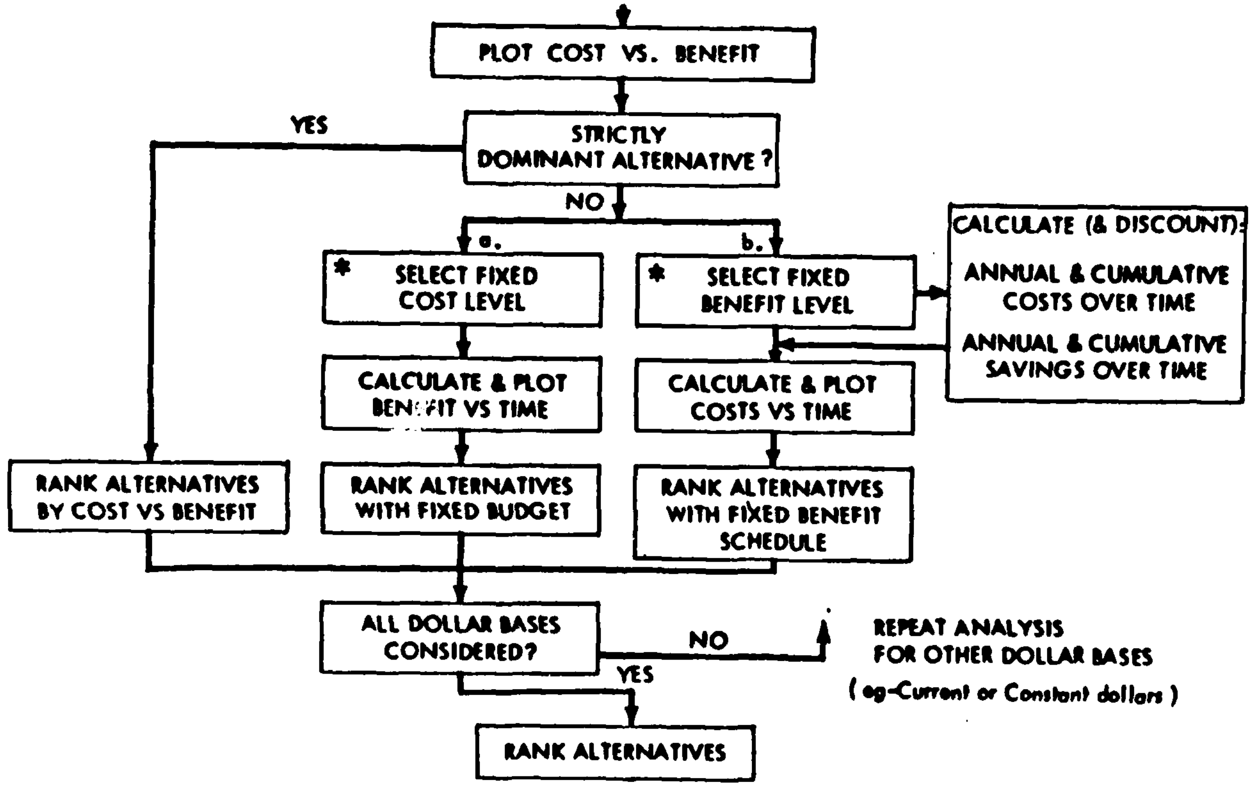
APPLICATION OF LCCA FOR AIRCRAFT TIRES

	PROCUREMENT BASED ON LOWEST COST	PROCUREMENT BASED ON LCC
INVESTMENT		
• UNIT COST	$ 95.09	$ 96.15
• SHIPPING COST	4.57	4.57
• COST TO INSTALL TIRE	10.42	10.42
TOTAL UNIT COST	$110.08	$111.14
NUMBER OF TIRES REQUIRED FOR 69,650 LANDINGS	4,109	3,247
DEVELOPMENT COSTS FOR IMPROVED TIRE		1,050
TOTAL COST FOR 69,650 LANDINGS	$452,319	$361,922
TOTAL SAVINGS DUE TO LCC		$ 90,397

APPLICATION OF LCCA TO AIRCRAFT HYDRAULIC FILTERS
(A COMPARISON OF A CLEANABLE VS. A DISPOSABLE FILTER)

	PRIOR PROCUREMENT	LCC PROCUREMENT
INVESTMENT		
• UNIT COST	$ 19.96	$ 12.90
• UNIT SHIPPING COST	.34	.34
OPERATING & MAINTENANCE		
• UNIT CLEANING COST (3 @ $7.05)	21.15	
• UNIT REMOVE & REPLACE COSTS		
(4 @ $7.20)	28.80	
(1 @ $7.20)		7.20
TOTAL LIFETIME COST/UNIT	$ 70.25	$ 20.44
HOURS OF SERVICE USE/UNIT	600	300
COST/HOUR USE	.11708	.06813
TOTAL FILTER HOURS OF USE REQUIRED	720,000	720,000
TOTAL COST FOR REQUIRED FILTER HOURS	$84,300	$49,056
TOTAL LCC (OPPORTUNITY) SAVINGS OF DISPOSABLE FILTER		$35,244

THE PROCESS OF COMPARING ALTERNATIVES



SOURCE: DOD ECONOMIC ANALYSIS HANDBOOK

THE LCC ENVIRONMENT AND EQUIPMENT APPLICATION SETTING

1. ORGANIZATION TYPE
   - GOVERNMENT (DEFENSE; NONDEFENSE)
   - COMMERCIAL (PUBLIC; PRIVATE)
   - THIRD SECTOR (CHARITIES; RESEARCH INSTITUTE; UNIVERSITIES; ETC.)
2. ACQUISITION STAGE
   - CONCEPTUAL
   - PROTOTYPE
   - PRODUCTION

THE LCCA ENVIRONMENT AND EQUIPMENT APPLICATION SETTING
(CONTINUED)

3. EQUIPMENT SCALE
   - A COMPLETE SYSTEM (AIRCRAFT; SUBWAY; COMMUNICATION SYSTEM; . . .)
   - A SUBSYSTEM (AVIONICS; ENGINE; AIRFRAME; . . .)
   - A COMPONENT (RADIO; COMPUTER; ITEM; . . .)
4. ACQUISITION STRATEGY
   - SINGLE VERSUS MULTIPLE BIDDERS
   - COMPETITIVE VERSUS NONCOMPETITIVE PROCUREMENT
   - CONTRACT TYPE/COMMITMENTS
5. EQUIPMENT APPLICATION
   - SINGLE SYSTEM VERSUS MANY SYSTEMS AND SETTINGS

THE LCCA ENVIRONMENT AND EQUIPMENT APPLICATION SETTING
(CONTINUED)

6. MAGNITUDE OF THE DESIGN EFFORT
   - SMALL SCALE
   - LARGE SCALE
7. OPERATIONS AND SUPPORT CONCEPT
   - WELL KNOWN/TRADITIONAL
   - REFERENCE CONCEPT EXISTS
   - NEW AND INNOVATIVE
   - BENIGN VERSUS HOSTILE
   - USER VERSUS CONTRACTOR CONTROL

THE LCCA ENVIRONMENT AND EQUIPMENT APPLICATION SETTING

(CONTINUED)

8. TIME AND COST OF LCCA

   - CAN EXPENSE BE JUSTIFIED
   - ROI (RETURN ON INVESTMENT)

9. DIFFERENCE IN LCC ACROSS ALTERNATIVES

   - SMALL VERSUS SIGNIFICANT
   - DEVELOPMENT VERSUS ACQUISITION VERSUS OWNERSHIP

10. SENSITIVITY OF LCC TO CURRENT DECISIONS

    - SMALL VERSUS SIGNIFICANT
    - DIRECT VERSUS INDIRECT

PRINCIPAL CONSTRAINTS ON LIFE CYCLE COST ANALYSIS

DATA

- MULTIPLE DATA PRODUCTS REQUIRED
- MULTIPLE NOMENCLATURE
- APPROXIMATE VALUES
- LIMITED HISTORICAL DATA BASE
- INTERSERVICE INCONSISTENCIES

METHODOLOGY

- PARTIAL COVERAGE
- LIMITED DISTINCTION BETWEEN POLICY AND DESIGN REQUIREMENTS
- LOGICAL LOOPHOLES
- LIMITED COMPONENT-SYSTEM COMPATIBILITY
- MODEL PROLIFERATION (NO STANDARDIZATION)
- INADEQUATE TREATMENT OF COST UNCERTAINTY
- POOR DOCUMENTATION

SUB-SET #6

LCCA METHODOLOGY

LIFE CYCLE COST ANALYSIS: WHY, WHAT AND HOW

- METHODOLOGY

LCCA: CONCEPTUAL ROOTS

- SYSTEMS ANALYSIS
  - AN APPROACH FOR ANALYZING COMPLEX PROBLEMS OF CHOICE UNDER VARYING DEGREES OF UNCERTAINTY
  - A SYSTEMATIC EXAMINATION OF OBJECTIVES IN A GIVEN AREA AND OF THE ALTERNATIVE WAYS AND COSTS OF ACHIEVING THOSE OBJECTIVES

THE BASIC SYSTEMS PROCESS

- AN ITERATIVE PROCEDURE INVOLVING:
  - FORMULATION
  - SEARCH
  - EVALUATION
  - INTERPRETATION
  - VERIFICATION

FUNDAMENTAL SYSTEM CHARACTERISTICS

- GOAL(S)
  - OBJECTIVE(S)
  - PERFORMANCE MEASURE(S)
- ENVIRONMENT
- RESOURCES
- COMPONENTS
- DECISION MAKER(S)

EXAMPLE OF A MILESTONE I SYSTEM PROGRAM DEFINITION STATEMENT (SPDS) FOR COMBAT VEHICLES

e proposed Tank System is a full tracked armored combat vehicle. It is designed to satisfy the U.S. Army Main Battle Tank quirement during the 1980's and beyond providing improved levels of protection, increased fire power and mobility over tanks currently in the U. S. Army inventory.

e proposed Tank System will not replace any existing tank family per se, but will be used to supplement the tank inventory and place the reference tank in TOE units. The reference tank will continue to operate in the U. S. Army inventory within selected . OE, TDA and TA units.

Alternative tank systems for evaluation purposes include the XYZ Corporation prototype and the ABC Corporation prototype, the ference system with an improved fire control system and increased horsepower and a foreign tank developed by MPD orporation.

		REFERENCE SYSTEM	PROPOSED SYSTEM
A.	MISSIONS		
	1. Primary	To provide battlefield mobile fire power for offensive combat command and control	Same
	2. Secondary	To provide rapid reaction strategic battlefield mobility and reconnaissance	Same
B.	CHARACTERISTICS		
	1. General		
	Weight (combat loaded)	104,000 lbs.	116,000 lbs.
	Weight (less crew, fuel and combat load)	97,000 lbs.	108,000 lbs.
	Unit Ground Preserve	13.5	12.7
	Crew	4	4
	DIMENSIONS		
	Height	128 ins.	125 ins.
	Width	144 ins.	144 ins.
	Length	366 ins.	366 ins.
	Ground Clearance	18 ins.	21 ins.
	Wheel Travel	10.1 ins.	15 ins.
	2. Performance Speed		
	Speed		
	Road	35 MPH	45 MPH Minimum 50 MPH Desired
	Cross Country	10 MPH	24 MPH
	Cruising Range	250 mi.	300 mi. Minimum 350 mi. Desired
	Slope Operation	60%	60%
	Trench	105 ins.	105 ins.
	Vertical Wall	36 ins.	36 ins.
	Fordability	48 ins.	48 ins.
	Gross HP to Weight Ratio	14.4 HP/Ton	25.8 HP/Ton
	3. Configuration		
	a. Engine		
	Make & Model Displacement Type Fuel Gross Horsepower	Continental AVDS 1790-2 1970 cubic inches 90° air cooled, 12 cyl., 4 cycle Diesel 750 HP	Two engine candidates are available. (1) AVCR 1360, a 1500 HP diesel fueled, air cooled, variable compression ratio engine, and (2) AGT 1500, a 1500 HP turbine engine with recuperator. The contractor may select one of these or any other engine which meets the needs.

EXAMPLE OF A MILESTONE I SYSTEM PROGRAM DEFINITION STATEMENT (SPDS) FOR COMBAT VEHICLES (Continued)

	REFERENCE SYSTEM	PROPOSED SYSTEM
b. Transmission		
Make & Model	Allison GM, CD 850-6	The Allison XR 1500 is available, but will require adaption to either engine candidate. The contractor may select it or any other transmission which meets the needs.
c. Running Gear		
Suspension Type	Return Roller	The contractors are to design the running gear to meet the needs of their system, within other specified system requirements.
Springing Media	Torsion Bar	
Number of Wheels	6 pairs (each side)	
Track Type	Steel, Double Pin, Detachable Pack	
Track Width	28 ins.	
d. Electrical System		
Generator		The contractors are to design the electrical system to meet the needs of their system, within other specified system requirements.
Amperes	300 Amperes	
Voltage	28 VDC	
Batteries	6TN (4 each)	
e. Armor		
See classified annex to this document		
f. Armament	1-105 MM Gun 1-Cal. 30 MG, M37 1-Cal. 50 MG, M2 Crew Weapon	1-105 MM M58 Gun 1-7.62 MM Co. Axial MG 1-7.62 MM Loaders Weapon 1-40 MM HVGL Cmdrs. Weapon
g. Turret		
Traverse	Continuous 360°	Continuous 360°
Elevation	-8° + 35°	-10° - 40°
Stabilization	Modification "add-on" available	Fully Stabilized
Munitions (stowed on-board)		
See classified annex to this document		
h. Fire Control System		
Rangefinder	M17C	A single integrated system to operate the 105MM gun which allows both the commander and the gunner to aim and fire the weapon. Co-axial weapon is slaved to the main weapon. A special purpose computer is required as an integral component to the fire control system. The computer may be digital or analog.
Computer	Ballistic M13A-1D	
Telescope	M105C	
Periscope	M27, M24, M13, M31	
Elevation Quadrant	M13A1	
Gunner Quadrant	M1A1	
Night Vision Sight	M36E2	
i. Communication		
Radio	AN/VRC-47 (1 set)	One half of the fleet to be equipped with AN/VRC-12
Interphone	AN/VIC-1, with 4 control boxes	Contractor to select appropriate intercom system, with 4 control boxes.

C. ACQUISITION POLICY

	REFERENCE SYSTEM	PROPOSED SYSTEM
1. Design to Cost Goal	none (unit cost $392K)	$663K Firm Commitment for average unit price (1975 dollars)
2. Number of Tanks (normalized to 3,312 deployed tanks)		
a. Deployed	2,667	The same deployed, training and pipeline ratios will apply for the proposed tank system. Time frame for deployment of the proposed tank system is based on the following funding schedule. Production follows funding by 12 months.
b. Training	430	
c. Pipeline	215	

FY	79	80	81	-	87	88	TOTAL
QTY	110	352	360	-	360	320	3,312

EXAMPLE OF A MILESTONE I SYSTEM PROGRAM DEFINITION STATEMENT (SPDS) FOR COMBAT VEHICLES (Continued)

		REFERENCE SYSTEM	PROPOSED SYSTEM
3.	Contract Commitments on Support Cost Control	None	Contractor to establish baseline and utilize LSAR system track and report support cost reduction achievements. RIW options are available on selected components and repair parts.
4.	Special Considerations for Multi National Application		

See Main Battle Tank Foreign Application Prepared by Department of Army, 5 April 1974 and NATO Agreement on Common Components, May 1975.

D. DEPLOYMENT SCHEDULE

See Main Battle Tank Distribution/Redistribution Plan (U) Prepared by U. S. Army Tank Automotive Command 8 February 1977 Classified: Confidential.

Operating and support costs for baseline and proposed system are based on deployment of 1940 tank systems to Europe according to the above plan.

E. SUPPORT CONCEPT

		REFERENCE SYSTEM	PROPOSED SYSTEM
1.	General	Standard 4 level (Org, Direct, General and Depot) maintenance concept defined and published Maintenance Allocation Chart and including 30% of available crew manpower expended for scheduled service and inspections.	Organizational Maintenance: Scheduled maintenance shall be conducted by the crew and organizational mechanics. Vehicle will have built-in indicators for fuel, air and oil filters to facilitate maintenance. Unscheduled maintenance will be limited to piece part or component replacement. Design is to allow 90% of vehicle malfunctions to be detected and corrected at this level. Direction and General Support Maintenance: Maintenance at the DS level of the vehicle is limited to end item repair by component replacement. In those instances where diagnostic equipment is available, repair will be authorized. At the GS level, components and assemblies will be repaired and returned to stock.
2.	Skill Requirements Automotive Weapon Station & Fire Control	 Low Moderate	An analysis, comparing the MOS's used in the reference tank system and those required for the proposed tank system indicates no need to establish new MOS's for the proposed tank system. The same MOS's with transitional training can qualify personnel to operate and maintain the proposed system.
3.	Support Equipment Automotive Weapon Station & Fire Control	 Simple Moderately Complex	Current assessment of the proposed Tank System design indicates a reduction in the number of special tools vis a vis those required to support the reference tank system. The assessment also indicates that the built in test points will reduce the requirement for special test equipment. A design requirement calls for the elimination or reduction of calibration requirements.
4.	Contractor Support	None	Limited contractor support will be used during initial fielding of the proposed Tank System. It is anticipated that this support will not be required after one year of fielded operations.

EXAMPLE OF A MILESTONE I SYSTEM PROGRAM DEFINITION STATEMENT (SPDS) FOR COMBAT VEHICLES (Continued)

	REFERENCE SYSTEM	PROPOSED SYSTEM
F. LOGISTIC GOALS		
1. System Goals		
a. System Reliability	150 MMBF	290 MMBF
b. Mission Reliability	212 MMBF	DT/OT II 272 MMBF DT/OT III 220 MMBF
c. Maintenance Ratio	1.63	1.25
d. Operational Ready Rate	0.94	0.95
e. Durability (overhaul point)	5,000 miles	6,000 miles
f. Average org/direct maintenance men per battalion	95	95
2. Subsystem Goals		
a. Power Package		
Reliability	1,000 MMBF	1,600 MMBF
Durability	4,000 MMTO	4,000 MMTO
Mean Time to Repair	4 hrs.	2 hrs.
b. Fire Control System		
Reliability	900 MMBF	1,200 MMBF
Durability	8,000 MMTO	15,000 MMTO
Mean Time to Repair	2 hrs.	1.2 hrs.

FORMULATING THE COST ANALYSIS

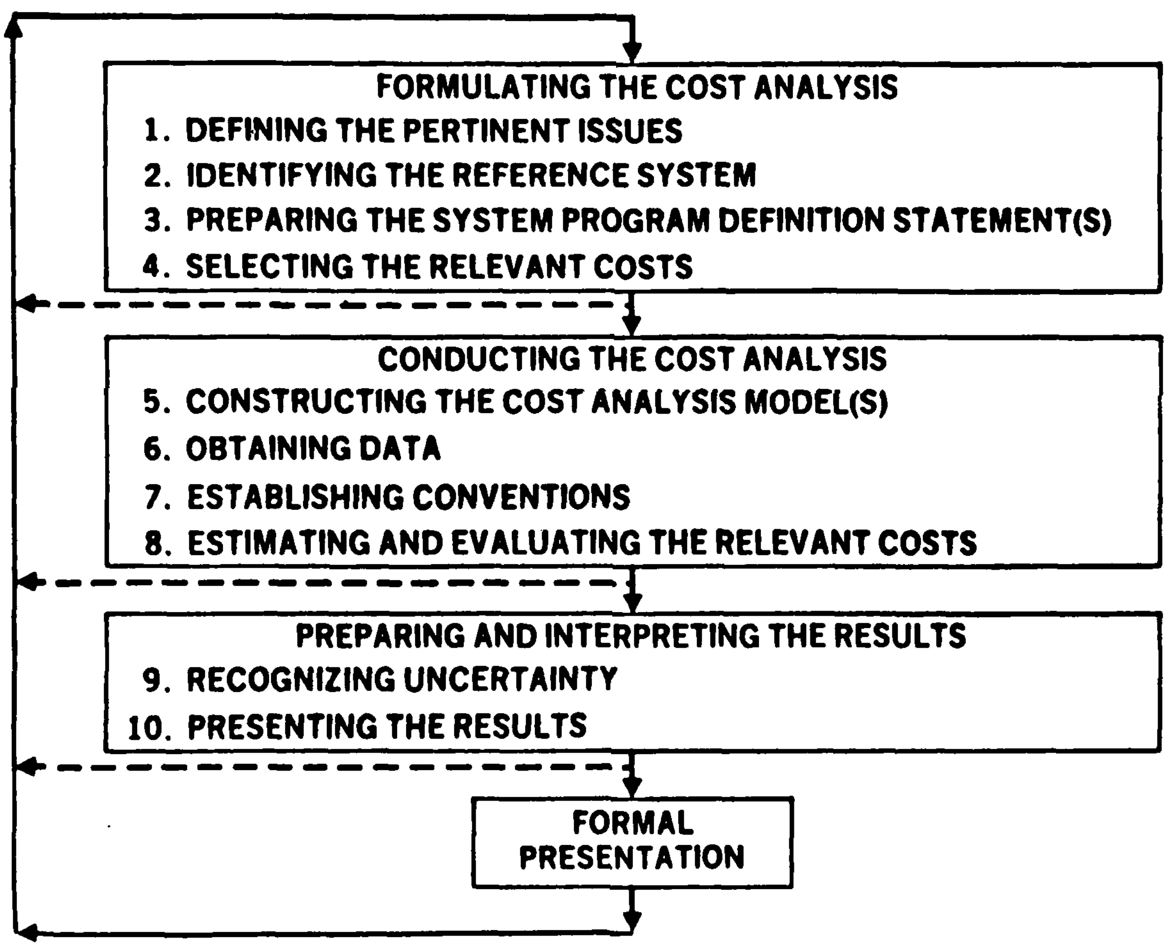
4. DEFINE AND APPLY THE COST ELEMENT STRUCTURE:

- PURPOSE:
  - TO DEFINE THE BASIC VOCABULARY
  - TO IDENTIFY THE RELEVANT COSTS
- OUTLINE OF GENERIC LCC CATEGORIES
  - DEVELOPMENT
  - INVESTMENT (PRODUCTION)
  - OPERATIONS AND SUPPORT
  - DISPOSAL

GENERIC LCC ELEMENT STRUCTURE - MAJOR WEAPON SYSTEMS

- 100 RESEARCH AND DEVELOPMENT
- 200 INVESTMENT
  - 201 SYSTEM INVESTMENT
  - 202 SUPPORT INVESTMENT
- 300 OPERATING AND SUPPORT
  - 301 DEPLOYED UNIT OPERATIONS
  - 302 INSTALLATION SUPPORT
  - 303 BELOW DEPOT MAINTENANCE
  - 304 DEPOT MAINTENANCE
  - 305 DEPOT SUPPLY
  - 306 TRANSPORTATION
  - 307 SUSTAINING INVESTMENTS
  - 308 PERSONNEL SUPPORT AND TRAINING
- 400 DISPOSAL

BASIC COST ANALYSIS METHODOLOGY



FORMULATING THE COST ANALYSIS

(PRE-ANALYSIS DISCUSSIONS)

1. ESTABLISH THE DECISION OBJECTIVES:

   - TO COMPARE ALTERNATIVES AND SELECT THE PREFERRED ONE
   - TO IMPROVE A GIVEN DESIGN
   - TO CONTROL A PROCUREMENT
   - TO MANAGE AN OPERATIONAL SYSTEM
   - TO IMPROVE PLANNING STRATEGIES

FORMULATING THE COST ANALYSIS

2. ESTABLISHING THE REFERENCE SYSTEM AND THE BASE CASE CONDITIONS

   - TO PROVIDE A CONTEMPORARY BASELINE
   - REQUIRES CONCENSUS FROM/AMONG
     - EXPECTED USER(S)
     - MANAGEMENT (REVIEWERS, ...)
     - ANALYSTS

EXAMPLES OF DISCUSSION TOPICS BY DEVELOPMENT PHASE

Categories	CONCEPT VALIDATION Army Helicopter	FULL-SCALE DVLPMT Navy Attack Aircraft	PRODUCTION Air Force Fighter
Proposed System	Light Helicopter (LHX)	Attack Aircraft (VAX)	Fighter (FXX)
Reference System	Existing Observation Helicopter (OHY)	Existing Attack Aircraft (AYJ)	Existing Fighter (FYC)
Alternatives	Concepts: Modified OHY Austere LHX Existing Foreign Helicopter	Designs: Alternative Prototype VAX Modified AY	Acquisition Policy: Change Initial Pro duction rate Retrofit Subsystem Use Backup Subsystem
Contents of Cost Presentation (includes a review of the minimum requirements)	Reference System, Proposed System(s) - Annual O&S Cost per Aircraft Total Time-phased O&S and Support Investment Costs - Helicopter O&S Cost Drivers - System Goals - Logistics Goals	Reference System, Proposed System(s) - Annual O&S Cost per Squadron - Total Time-phased O&S and Support Investment Costs - Annual Maintenance Cost by Subsystem (scheduled and unscheduled) - Historical Fighter and Attack Aircraft O&S Drivers, and their Estimates - System and Subsystem Goals	Reference System, Proposed System(s) Annual O&S Cost per Squadron - Total Time-phased O&S and Support Investment Costs - Annual Maintenance Cost by Subsystem (scheduled and unscheduled) - Historical Fighter O&S Cost Drivers and Estimates - Progress in Meeting System and Subsystem O&S Goals
Special Issues	- Comparison of Alternative System Concepts - Sensitivity of LHX O&S Cost to Characteristics of Mission Equipment Package - Uncertainty in Estimates	- Risks in Engine Development and their Impacts on O&S Requirements - Alternative Support Strategies	- Use of Contractors for Initial Support - Funding of Reliability Improvement Program

FORMULATING THE COST ANALYSIS

3. PREPARE THE LCCA - SYSTEMS DEFINITION STATEMENT

   - PURPOSE

     - REFLECTS THE USING ORGANIZATION'S UTILIZATION AND SUPPORT CONCEPT
     - CONTAINS THE ESSENTIAL ASSUMPTIONS TO INTERPRET THE COST ESTIMATES CORRECTLY
     - PROVIDES AN HISTORICAL TRAIL ON THE EVOLUTION OF THE SYSTEM DESIGN AND COST ESTIMATES
     - ESTABLISHES A FORMAL SYSTEMS PERSPECTIVE OF THE ITEM OR CAPABILITY UNDER CONSIDERATION

3. PREPARE THE LCCA - SYSTEMS DEFINITION STATEMENT (CON'T)

- OUTLINE
  - ITEM MISSION/OBJECTIVE/FUNCTION
  - CHARACTERISTICS
    - PHYSICAL
    - PERFORMANCE
    - EXPECTED OPERATIONAL LIFE
    - OPERATIONAL REQUIREMENTS
  - ACQUISITION POLICY
    - SCHEDULE & QUANTITY
    - DESIGN TO COST GOAL(S)
    - CONTRACT TYPE/COMMITMENTS
    - MULTI-NATIONAL CONSIDERATIONS
  - UTILIZATION PLAN
  - SUPPORT CONCEPT
  - LOGISTICS GOALS
    - RELIABILITY/MAINTAINABILITY GOALS

BASIC OUTLINE OF A SYSTEM PROGRAM DEFINITION STATEMENT FOR AIRCRAFT SYSTEMS

A. MISSION PROFILE
   1. Primary
   2. Secondary

B. AIRCRAFT CHARACTERISTICS
   1. Performance characteristics
   2. Physical characteristics
   3. Expected operational life
   4. Crew requirements

C. ACQUISITION PROGRAM
   1. Design-to-cost goal
   2. Number of Aircraft
      a. Deployed
      b. Training
      c. Pipeline
      d. Attrition
   3. Production/Deployment schedule
   4. Contract commitments on support cost control
   5. Special considerations for multi-national application

D. DEPLOYMENT
   1. Peacetime
      a. Number of CONUS/overseas bases
      b. Number and types of deployable units per base
      c. Number of aircraft per Training/Deployed Units
      d. Flying program (Training/Deployed Units)
   2. Contingency/Wartime Capability
      a. Number of CONUS/Overseas bases
      b. Number and type of deployable units per base
      c. Number of aircraft per Training/Deployed Units
      d. Flying program (Training/Deployed Units)

E. SUPPORT CONCEPT
   1. Initial Support
      a. Organization (Note: For Navy and Marine Aircraft indicate land and carrier plans.)
      b. Location of initial operational unit(s)
      c. Use of contractor support
      d. Parts supply
      e. Initial training
   2. Mature System Support - For Each Echelon, Generally Described
      a. Organization (Note: For Navy and Marine Aircraft indicate land and carrier plans.)
      b. Functions performed
      c. Method of performance
      d. Skill requirements
      e. Support equipment requirements
      f. Workload

F. LOGISTICS GOALS
   1. Weapon System Goals
      a. Serial reliability
      b. Aircraft mean time to repair
      c. Operational ready rate
      d. Number of organizational and intermediate maintenance personnel per unit
   2. Subsystem Goals
      a. Engines
      b. Avionics
   3. Component Goals
      a. Radar
      b. Inertial Navigation System

EXAMPLE OF A CONCEPT VALIDATION SYSTEM PROGRAM DEFINITION STATEMENT FOR ADVANCED LIGHT HELICOPTERS

	Reference System	Proposed System
A. MISSIONS		
1. Primary	Reconnaissance, Command & Control, Scout	Scout
2. Secondary	Transportation	Reconnaissance, Command & Control, Transportation
B. CHARACTERISTICS		
1. Performance		
a. Maximum Speed/Range/Endurance	130 mph/260 Miles/3 Hours	150 mph/350 Miles/35 Hours
b. Maximum Rate of Climb[1]	1,800 ft./min.	2,000 ft./min.
c. Payload		
- Sea Level Standard Day[1]	455 lb.	1,000 lb.
- 6,000 ft. @90°F.	50 lb.	700 lb.
d. Mission Equipment Package (MEP)	None	Target Acquisition and Designation System; Pilot Night Vision System
2. Configuration		
a. Airframe	Aluminum; 2 passenger, 2 crew; skid landing gear	Aluminum and Composite; 2 pass., 2 crew; wheeled landing gear
b. Propulsion	One-Allison 763A-700 Turboshaft Engine with 317 SHP	One GE T700 Modular Turboshaft Engine with 1536 SHP; common to UTTAS & AAH
c. Rotors	2-17'8" Aluminum D spar; no damping	4-12' Fiberglass; elastomeric bearings damping
d. Avionics	Standard	Standard; Mission Equipment Package (MEP)
e. Empty Weight	1,530 lb.	4,000 lb. including 650 lb. MEP
3. Expected Operational Life	8 years (remaining)	15 years
C. ACQUISITION POLICY		
1. Design-to-Cost Goal (including the allocation of costs to hardware levels required by the O&S cost analysis)	None (unit cost $140K)	$1.1M prototype aircraft; $1.4M cumulative average cost at 100th production unit
2. Number of Aircraft	(normalized to 540 deployed aircraft)	
a. Deployed	540	540
b. Training	40	50
c. Pipeline	85	80
d. Attrition	35	30
3. Production/Deployment Schedule	8 per month for 2 years, then 18 per month to end of run	6 per year Low Rate Initial Production (LRIP) for 2 years, then 10 per mn. to end of run
4. Contract Commitments on Support Cost Control	None	RIW being considered
5. Special Considerations for Multi-National Application	None	None

[1] Different Conditions including weight, configuration, and altitude from other stated characteristics.

EXAMPLE OF A CONCEPT VALIDATION : SYSTEM PROGRAM DEFINITION STATEMENT FOR ADVANCED LIGHT HELICOPTERS (Continued)

	Reference System	Proposed System
D. DEPLOYMENT		
1. Number of Equipped Units CONUS/Overseas	40/14	
2. Average Aircraft per Unit	12	12
3. Flying Hours per Month Peacetime/Contingency	25/30	20/30
E. SUPPORT CONCEPT		
1. General Description	Transitioning to 3 level (AVUM AVIM, Depot) maintenance concept defined in published Maintenance Allocation Chart including 40% of on-equipment manpower expended on scheduled inspections. Engine teardown at Depot only.	Standard Army 3 level (AVUM AVIM, Depot) concept, greatly reduced scheduled inspections by applying on-condition maintenance philosophy. Engine modules will be interchangeable at intermediate level.
2. Skill Requirements	Low	Moderate (greater than for the Reference System)
3. Support Equipment	Simple	Complex for MEP
4. Contractor Support	None	Initial field and depot for MEP and engine. RIW items (if selected) for four years.
F. LOGISTIC GOALS		
1. Weapon System Goals		
a. System Reliability	1.5 MTBF	2.5 MTBF
b. Maintenance Man Hours per Flight Hour	5.1	6.0
c. Operational Ready Rate	70%	80%
d. Average Organizational/Intermediate Maintenance Men per Company	50	40
2. Subsystem Goals		
a. Engines		
1) Flying Hours Between Overhauls	750	2,000
2) Mean Flying Hours Between Failure (MFHBF)	44	100
3) Time Required to Change Engines	4 hrs.	2 hrs.
b. Avionics		
1) MFHBF	316 hrs.	100 hrs. (includes MEP)
2) Average Organizational/Intermediate Maintenance Men per Company	2	4
3. Component Goals		
a. Target Acquisition & Designation System		
1) MFHBF	N/A	200 hrs.
2) Unit Cost	N/A	$300K
b. Pilot Night Vision System		
1) MFHBF	N/A	350 hrs.
2) Unit Cost	N/A	$100K

COMBAT VEHICLE SYSTEM PROGRAM DEFINITION STATEMENT (SPDS)

- MISSION
  - TYPES
- CHARACTERISTICS
  - PHYSICAL
  - PERFORMANCE
  - EXPECTED OPERATIONAL LIFE
  - MUNITIONS
  - CREW REQURIEMENTS
- ACQUISITION POLICY
  - SCHEDULE & QUANTITY
  - DESIGN TO COST GOAL
  - CONTRACT TYPE/COMMITMENTS
  - MULTI-NATIONAL CONSIDERATIONS
- DEPLOYMENT
  - PEACETIME
  - WARTIME
  - RESERVES
- SUPPORT CONCEPT
  - INITIAL SUPPORT
  - MATURE SUPPORT
- LOGISTICS GOALS
  - RELIABILITY/MAINTAINABILITY GOALS (BY SYSTEM; SUBSYSTEM; COMPONENTS)

AIRCRAFT COST ELEMENT STRUCTURE

100 Research and Development

200 Investment

- 201 System Investment
- 202 Support Investment
  - 202.1 Support Equipment
  - 202.2 Training Equipment and Services
  - 202.3 Documentation
  - 202.4 Initial Spares and Repair Parts
  - 202.5 Spare Engines
  - 202.6 Facilities (Non-production)
  - 202.7 War Reserve Materiel
    - 202.7.1 Spares
    - 202.7.2 Repair Parts
    - 202.7.3 Munitions
    - 202.7.4 Missiles
    - 202.7.5 Sonobuoys
    - 202.7.6 Tanks, Racks, Adapters & Pylons

300 Operating and Support

- 301 Deployed Unit Operations
  - 301.1 Aircrews
  - 301.2 Command Staff
  - 301.3 POL
  - 301.4 Security
  - 301.5 Other Deployed Manpower
  - 301.6 Personnel Support

- 302 Below Depot Maintenance
  - 302.1 Aircraft Maintenance Manpower
  - 302.2 Ordnance Maintenance Manpower
  - 302.3 Maintenance Materiel
  - 302.4 Personnel Support

- 303 Installations Support
  - 303.1 Base Operating Support
  - 303.2 Real Property Maintenance
  - 303.3 Personnel Support

- 304 Depot Maintenance
  - 304.1 Manpower
  - 304.2 Materiel

- 305 Depot Supply
  - 305.1 Materiel Distribution
  - 305.2 Materiel Management
  - 305.3 Technical Support

- 306 Second Destination Transportation

- 307 Personnel Support and Training
  - 307.1 Individual Training
  - 307.2 Health Care
  - 307.3 Personnel Activities
  - 307.4 Personnel Support

- 308 Sustaining Investments
  - 308.1 Replenishment Spares
  - 308.2 Modifications
  - 308.3 Replenishment Ground Support Equipment
  - 308.4 Training Ordnance
    - 308.4.1 Munitions
    - 308.4.2 Missiles
    - 308.4.3 Sonobuoys

SOME SPECIAL COST ELEMENT STRUCTURE CONSIDERATIONS

- LEVELS OF COST AGGREGATION
- VARIABILITY OF COST ELEMENTS
- COLLATERAL COSTS

LEVEL OF COST ANALYSIS DETAIL DEPENDS ON PROBLEM, SUBSYSTEMS, STATUS OF ACQUISITION PROGRAM

WORK UNIT CODE

AIRFRAME

- 11 AIRFRAME
- 12 COCKPIT & FUSE COMPARTMENT
- 13 LANDING GEAR
- 14 FLIGHT CONTROLS
- 24 SECONDARY POWER
- 41 ECS
- 42 ELECTRICAL
- 44 LIGHTING
- 45 HYDRAULICS
- 47 OXYGEN SYSTEM
- 91 EMERGENCY EQUIPMENT
- 97 EXPLOSIVE DEVICES

PROPULSION

- 23 ENGINE

AVIONICS

- 51 INSTRUMENTS
- 52 AUTOPILOT
- 55 MAL ANAL, ETC
- 57 INT GUID, ETC
- 63 UHF COMM
- 65 IFF
- 71 RADIO NAV
- 74 FIRE CONTROL
- 75 WPNS DEL
- 76 TEWS

71 RADIO NAV:

- 71A INS
- 71B DIRECTION FINDER
- 71D ILS
- 71D TACAN
- 71F ATT. HD. REF.

71D TACAN:

- 71DA REC-XMTR
- 71DB ANTENNA
- 71DC ANTENNA
- 71DD SW, RAD. FREQ.

LEVEL I (SUBSYSTEM)	LEVEL II (COMPONENTS)	LEVEL II (ITEM-3RD LEVEL)	LEVEL IV (ITEM-4TH LEVEL)

LEVELS OF ANALYSIS

COST ELEMENT ALLOCATION/VARIABILITY

SELECTED COST ELEMENTS	SINGLE AIRCRAFT	DEPLOYABLE UNIT	FLEET
202 SUPPORT INVESTMENT			
202.1 SUPPORT EQUIPMENT		X*	X
202.2 TRAINING EQUIPMENT AND SERVICES			X
202.3 DOCUMENTATION			X
202.4 INITIAL SPARES AND REPAIR PARTS	X	X	X
202.5 SPARE ENGINES	X	X	X
202.6 FACILITIES (NON-PRODUCTION)		X*	X
202.7 WAR RESERVE MATERIEL			X
300 OPERATING AND SUPPORT			
301 DEPLOYED UNIT OPERATIONS	X	X	X
302 BELOW DEPOT MAINTENANCE	X	X	X
303 INSTALLATION SUPPORT		X	X
304 DEPOT MAINTENANCE	X	X	X
305 DEPOT SUPPLY			X
306 SECOND DESTINATION TRANSPORTATION		X	X
307 PERSONNEL SUPPORT AND TRAINING		X	X
308 SUSTAINING INVESTMENTS		X	X

*THE COSTS OF SUPPORT EQUIPMENT AND FACILITIES REQUIRED FOR DEPOT OR FLEET SUPPORT ARE NOT TO BE ALLOCATED TO DEPLOYABLE UNITS.

COLLATERAL COSTS

- ASSOCIATED SYSTEMS
  - -- SUPPORT INVESTMENT
  - -- OPERATIONS & SUPPORT

ILLUSTRATION: COLLATERAL COSTS (NAVY SETTING)

310 ASSOCIATED SYSTEMS

- 311 SUPPORT INVESTMENT
  - 311.1 MOBILE LOGISTIC SUPPORT FORCE
  - 311.2 TENDERS AND REPAIR SHIPS
  - 311.3 ASHORE INTERMEDIATE MAINTENANCE ACTIVITY (IMA)
- 312 OPERATION AND SUPPORT
  - 312.1 MOBILE LOGISTIC SUPPORT FORCE
  - 312.2 TENDERS AND REPAIR SHIPS
  - 312.3 ASHORE INTERMEDIATE MAINTENANCE ACTIVITY (IMA)
  - 312.4 EMBARKED SYSTEMS

COST ESTIMATING PROCESS
(CONTINUED)

5. CONSTRUCT THE COST ANALYSIS MODEL(S)

6. DATA COLLECTION AND ANALYSIS

7. ESTABLISH CONVENTIONS

8. ESTIMATE AND EVALUATE THE RELEVANT COSTS/BENEFITS/EFFECTIVENESS

9. RECOGNIZING UNCERTAINTY

10. PRESENTING THE RESULTS

WHAT IS DONE IN THESE STEPS IS A FUNCTION OF THE DECISION OBJECTIVES AND DEFINITIONS, FEASIBILITY AND RESOURCE CONSTRAINTS, AND THE IMPORTANCE OF THE FOLLOWING FACTORS:

IMPORTANT FACTORS IN LCCA

- UNCERTAINTY/RISK/SENSITIVITY/ANALYSIS
- DISCOUNTING/PRESENT VALUE ANALYSIS
- INFLATION/RELATIVE INFLATIONARY IMPACTS
- STRUCTURE OF LCC - PROCUREMENTS
- RELEVANT VARIABLE COSTS
- BUDGET IMPACT ANALYSIS
- NORMATIVE vs. HISTORICAL COSTS
- SIGNIFICANT COSTS AND MAJOR COST DRIVERS
- REPARABLE vs. NON-REPARABLE APPLICATIONS
- COST OF OWNERSHIP PITFALLS
- QUANTITY ADJUSTMENTS
- VALIDATING THE ESTIMATE
- MATURITY CONSIDERATIONS
- ROLES OF GOVERNMENT, CONTRACTOR

SUB-SET #7

LCCA SPECIFIC MEASUREMENT PROBLEMS AND TECHNIQUES

LIFE CYCLE COST ANALYSIS: IMPORTANT CONSIDERATIONS

- COST ESTIMATING TECHNIQUES AND EFFECTIVENESS MEASURES

COST ESTIMATING TECHNIQUES

CONCEPT

- A JUDGMENT OR CALCULATED OPINION REGARDING THE COST OF AN ITEM

BASIC ASSUMPTION

- PAST EXPERIENCE IS A RELIABLE GUIDE TO THE FUTURE

BASIC SITUATIONS

- THE RELATIONSHIP BETWEEN PAST EXPERIENCE AND FUTURE APPLICATION IS RATHER DIRECT AND OBVIOUS
- THE RELATIONSHIP IS NOT OBVIOUS BECAUSE THE NEW ITEM IS SIGNIFICANTLY DIFFERENT IN SOME ENGINEERING OR FUNCTIONAL WAY FROM ITS PREDECESSORS

COST ESTIMATING TECHNIQUES

SELECTION CRITERIA

1. THE PROBLEM CONTEXT
   - THE DECISION TO BE MADE
   - THE REQUIRED ACCURACY AND RESOLUTION
   - THE COMPLEXITY OF THE PROBLEM
   - THE DEVELOPMENT STATUS OF THE ITEM
2. OPERATIONAL CONSIDERATIONS
   - THE DATA AVAILABLE
   - THE TIME AVAILABLE TO DO THE ANALYSIS
   - THE REQUIRED LEVEL OF EFFORT

COST ESTIMATING TECHNIQUES: SPECTRUM

SIMPLE ● ANALOG'S

SCALING

SUBJECTIVE ESTIMATES

ACCOUNTING - FACTOR MODELS

STATISTICAL - PARAMETRIC MODELS

ENGINEERING (BOTTOM-UP) MODELS

SIMULATION (PROCESS, EVENT) MODELS

COMPLEX ●

BASIC COST ESTIMATING TECHNIQUES

- ANALOGY (SAME TO SAME)

$$C_{NEW} = C_{OLD}$$

EXAMPLES

- MATERIEL COST STANDARD
- CONTRACTED PAY RATES
- INSTALLATION COST STANDARD
- MANAGEMENT COST STANDARD

BASIC COST ESTIMATING TECHNIQUES

- SCALING

  (LIKE TO LIKE; LINEARLY PROPORTIONAL)

  $C_{NEW} = \beta \cdot C_{OLD}$

  $\beta =$ SCALING FACTOR; USUALLY A RATIO

<u>EXAMPLE</u>

- OLD ITEM A AND NEW ITEM B DO THE SAME MECHANICAL FUNCTION
- ITEM B HAS 40 PERCENT FEWER PARTS THAN ITEM A
- FOR THESE ITEMS MAINTENANCE MATERIAL COSTS ARE A LINEAR FUNCTION OF THE NUMBER OF PARTS

$\text{MATERIAL COSTS}_{\text{ITEM B}} = (0.60)\ \text{MATERIAL COSTS}_{\text{ITEM A}}$

ACCOUNTING-FACTOR MODELS (SAMPLE)

(1) DEFENSE MATERIAL SYSTEM LIFE CYCLE COST MODEL

(2) AIR FORCE, COST ANALYSIS COST ESTIMATING (CASE) MODEL

(3) NAVY, LIFE CYCLE COST GUIDE FOR MAJOR WEAPON SYSTEMS

(4) ARMY, LIFE CYCLE COST MODEL

ILLUSTRATION OF AN ACCOUNTING MODEL EQUATION/STRUCTURE

Depot Maintenance Personnel
(Depot Overhaul Cost)

COST FORMULA

$$\begin{bmatrix}\text{DEPOT}\\ \text{MAINTENANCE}\\ \text{PERSONNEL}\\ \text{COST}\end{bmatrix} = \begin{bmatrix}\text{DEPOT}\\ \text{OVERHAUL}\\ \text{RATE}\end{bmatrix} \times \begin{bmatrix}\text{QUANITY OF}\\ \text{OPERATIONAL}\\ \text{EQUIPMENT}\end{bmatrix} \times \left[\begin{bmatrix}\text{EQUIPMENT}\\ \text{OVERHAUL}\\ \text{COST}\end{bmatrix} + \begin{bmatrix}\text{EQUIPMENT}\\ \text{TRANSPORTATION}\\ \text{COST}\end{bmatrix}\right]$$

WHERE:

$$\begin{bmatrix}\text{EQUIPMENT}\\ \text{OVERHAUL}\\ \text{COST}\end{bmatrix} = 0.809 \begin{bmatrix}\text{UNIT}\\ \text{PRODUCTION}\\ \text{COST}\end{bmatrix}^{0.881}$$

AND,

$$\begin{bmatrix}\text{EQUIPMENT}\\ \text{TRANSPORTATION}\\ \text{COST}\end{bmatrix}^{**} = 2 \times \begin{bmatrix}\text{Unit}\\ \text{Weight}\end{bmatrix} \times \begin{bmatrix}\text{COST OF TRANSPORTATION}\\ \text{AND PACKAGING}\end{bmatrix}$$

COST FACTORS	VALUE	UNITS
DEPOT OVERHAUL RATE	20%	PERCENT/YEAR
QUANTITY OF OPERATIONAL EQUIPMENT		UNITS
UNIT PRODUCTION COST	FROM 3.1	$
EQUIPMENT OVERHAUL COST		$ /UNIT
EQUIPMENT TRANSPORTATION COST		$ /UNIT
UNIT Weight		POUNDS
COST OF TRANSPORTATION AND PACKAGING	$0.50	$/POUND

** *Equipment transportation cost may also be calculated by the following:*

$$2 \times \begin{bmatrix}\text{Unit}\\ \text{Weight}\end{bmatrix} \times \begin{bmatrix}\text{Distance}\end{bmatrix} \times \begin{bmatrix}\$.00013 \text{ per lb-mi}\end{bmatrix}$$

STATISTICAL - PARAMETRIC MODELS (SAMPLE)

(1) RCA, PROGRAMMED REVIEW OF INFORMATION FOR COSTING AND EVALUATION (PRICE)

(2) USAF, COST ANALYSIS OF AVIONICS EQUIPMENT

(3) NAVY, IMPROVED LIFE CYCLE COST ESTIMATING

(4) USAF, SOFTWARE COST ESTIMATING METHODOLOGY

BASIC COST ESTIMATING TECHNIQUES

- STATISTICAL-PARAMETRIC ANALYSIS

$C_{NEW} = a + \beta_i X_i$

OR $= a \; X_i^{\beta_i} + j$

X_i = PARAMETER i

β_i = COEFFICIENT i

EXAMPLES

AIRCRAFT AIRFRAME PRODUCTION COSTS:

CUMULATIVE LABOR $= 28.9\, A^{0.74}\, S^{0.54}\, Q^{0.52}\, L$

CUMULATIVE MATERIAL $= 37.6\, A^{0.69}\, S^{0.62}\, Q^{0.79}$

A = AMPR WEIGHT

S = MAXIMUM SPEED AT ALTITUDE

Q = CUMULATIVE QUANTITY PRODUCED

L = COMPOSITE LABOR RATE

FITTING PARAMETRIC RELATIONSHIPS TO DATA

- THREE COMMON METHODS

  1. SELECTED POINTS
  2. AVERAGES
  3. LEAST SQUARES

- QUALITY OF FIT (USEFUL MEASURES)

  1. COEFFICIENT OF VARIATION
     - ON SAMPLE POINTS
  2. STANDARD DEVIATION
     - ON NONSAMPLE POINTS WITHIN THE SAMPLE RANGE
  3. STANDARD ERROR OF PREDICTION
     - ON POINTS BEYOND THE SAMPLE RANGE

COMMON FUNCTIONAL FORMS USED IN ESTIMATING RELATIONSHIPS

STRAIGHT LINE	$Y = A + BX$
PARABOLA	$Y = A + BX + CX^2$
EXPONENTIAL	$Y = AB^X$
POWER FUNCTION	$Y = AX^B$

COMPARISON OF LINEAR AND POWER FUNCTIONS

CHARACTERISTIC	LINEAR FUNCTION $A_0\ (1+MG)$	POWER FUNCTION $A_0\ (1+G)^M$
MARGINAL COST	CONSTANT	VARIABLE
COST ELASTICITY	VARIABLE	CONSTANT
ERROR VALUE	CONSTANT	PROPORTIONAL

ENGINEERING MODELS (SAMPLE)

(1) AIR FORCE, LOGISTICS SUPPORT COST MODEL

(2) AIR FORCE, OPTIMAL REPAIR LEVEL ACTIVITY (ORLA) MODEL

(3) NAVY, LEVEL OF REPAIR ANALYSIS (LORA) MODEL

(4) ARMY, LEVEL OF REPAIR MODEL

(5) AIR FORCE, LIFE CYCLE COST AND TEST AND EVALUATION MODELS

BASIC COST ESTIMATING TECHNIQUES

- DETAILED ENGINEERING ANALYSIS

$$C_{NEW} = \sum_{i=1}^{N} a_i C_{i(NEW)}$$

C_i = COST OF COMPONENT i

EXAMPLE

AIRCRAFT ON-EQUIPMENT MAINTENANCE COSTS

$$\sum_{i=1}^{N} \left[\frac{(TFFH)(QPA_i)(BLR)}{MFTBMA_i} \right] \left[(RIP_i)(IMH_i) + (1 - RIP_i)(RMH_i) \right] (K_{UTILIZATION}) + \frac{(TFFH)(SMH)(BLR)}{(SMI)}$$

i = ITEM i
TFFH = TOTAL FLEET FLYING HOURS
QPA_i = QUANTITY OF ITEM i ON AIRCRAFT
$MFTBMA_i$ = MEAN FLYING TIME BETWEEN MAINTENANCE ACTION FOR ITEM i
BLR = BASE LABOR RATE
RIP_i = PERCENT OF ITEM i FAILURES REPAIRED IN PLACE
IMH_i = AVERAGE MAN-HOURS TO REPAIR ITEM i IN PLACE
RMH_i = AVERAGE MAN-HOURS TO REMOVE AND REPLACE ITEM i
SMH = AVERAGE SCHEDULED MAINTENANCE HOURS
SMI = SCHEDULED MAINTENANCE INTERVAL

SIMULATION MODELS (SAMPLE)

1. AIR FORCE, MOD-METRIC MODEL
2. AIR FORCE, LOGISTICS COMPOSITE MODEL (LCOM)
3. NAVY, CARRIER AIRCRAFT SUPPORT EFFECTIVENESS EVALUATIONS (CASEE) MODEL
4. ARMY, ARMY RELIABILITY AND MAINTAINABILITY SIMULATION (ARM II) MODEL

SUB-SET #8

RE-INTEGRATION OF COST AND PERFORMANCE

LIFE CYCLE COST ANALYSIS: IMPORTANT CONSIDERATIONS

6. FACTORS THAT DRIVE COST AND EFFECTIVENESS

SYSTEM COST AND EFFECTIVENESS DRIVING FACTORS

- ITEM MISSION/OBJECTIVE/FUNCTION*
- CHARACTERISTICS
  - PHYSICAL*
  - PERFORMANCE
  - EXPECTED OPERATIONAL LIFE*
  - OPERATIONAL REQUIREMENTS
- ACQUISITION POLICY
  - SCHEDULE & QUANTITY*
  - DESIGN TO COST GOAL(S)
  - CONTRACT TYPE/COMMITMENTS
  - MULTI-NATIONAL CONSIDERATIONS

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*DENOTES FACTORS MOST COMMONLY UTILIZED IN COST MODELS

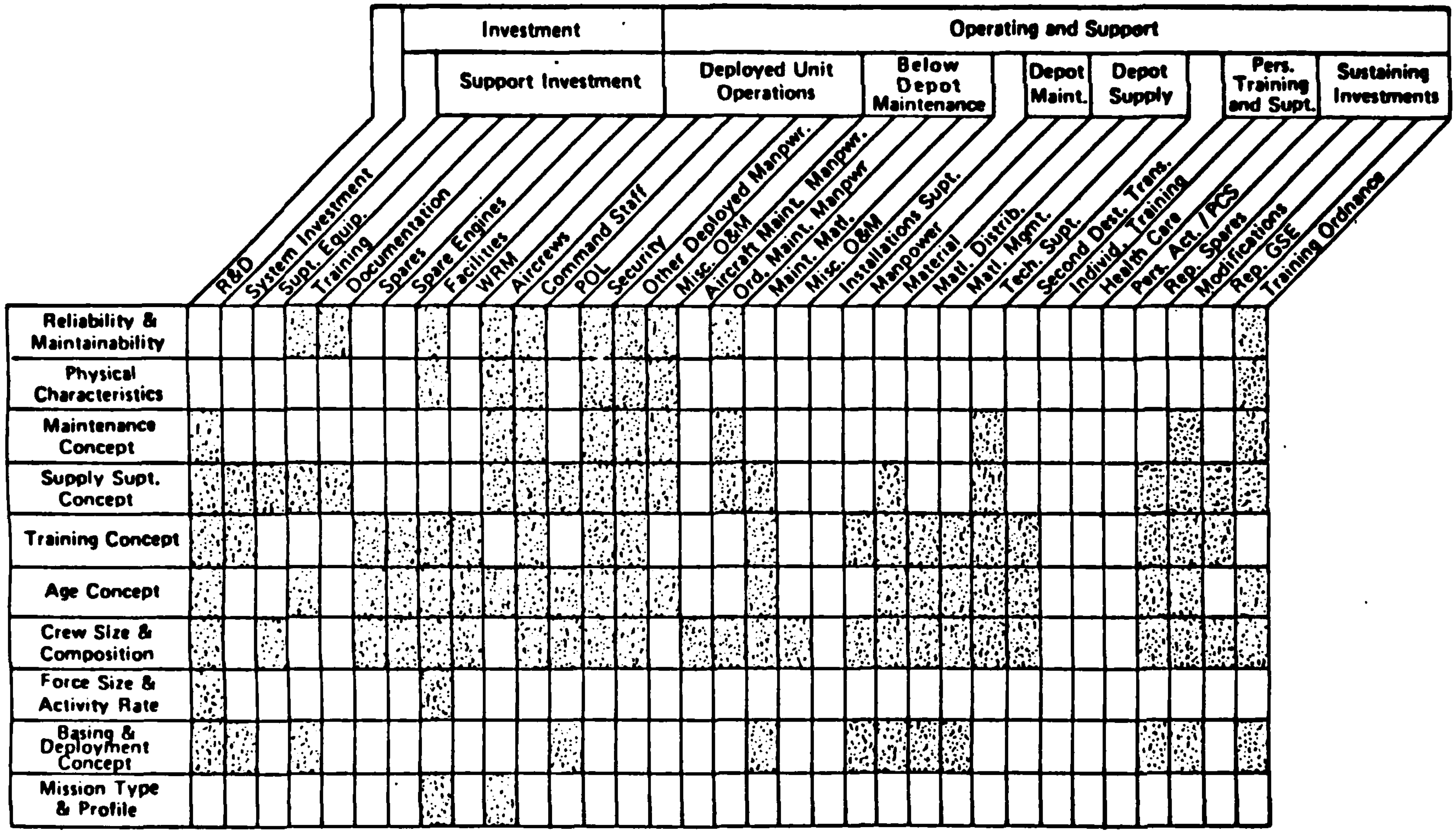
SYSTEM COST AND EFFECTIVENESS DRIVING FACTORS

- INHERENT PHYSICAL/DESIGN CHARACTERISTICS
  - RELIABILITY*
  - MAINTAINABILITY*
  - AVAILABILITY*
- SUPPORT CONCEPT
  - MAINTENANCE CONCEPT
  - SUPPLY SUPPORT CONCEPT*
  - TRAINING CONCEPT*
  - SUPPORT EQUIPMENT*
- UTILIZATION/OPERATING CONCEPT
  - CREW SIZE AND COMPOSITION*
  - FORCE SIZE AND ACTIVITY RATE(S)*
  - BASING AND DEPLOYMENT CONCEPT*
- LOGISTICS GOALS
  - RELIABILITY/MAINTAINABILITY GOALS

---

*DENOTES FACTORS MOST COMMONLY UTILIZED IN COST MODELS

RELATING COST DRIVING FACTORS TO COST ELEMENTS



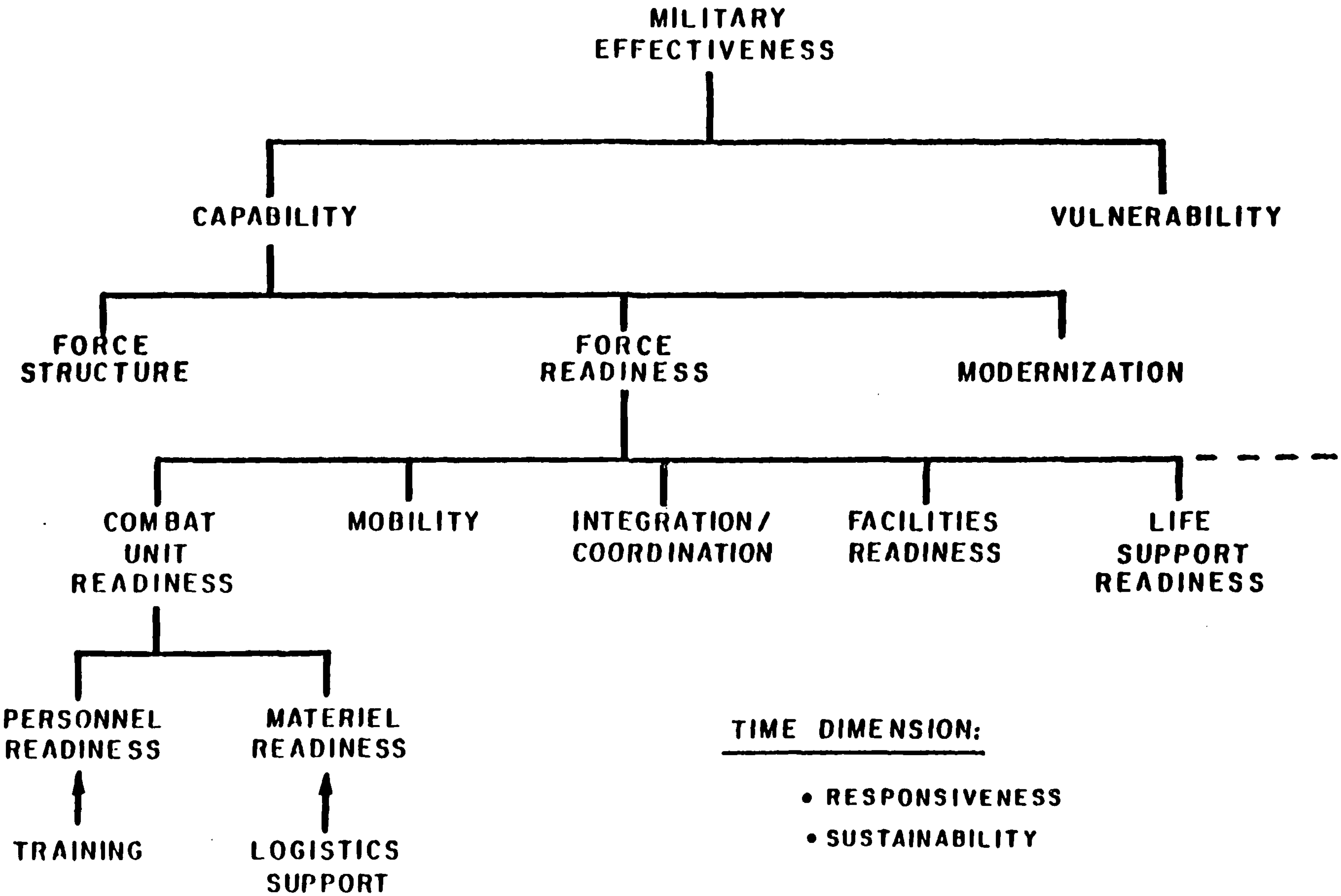
KEY:

☐ Cost - driving relationship expected

▨ No cost - driving relationship expected

SOURCE: MARKS, MASSEY, BRADLEY, RAND REPORT R - 2287, OCTOBER 1978.

READINESS TAXONOMY



TIME DIMENSION:

- RESPONSIVENESS
- SUSTAINABILITY

SYSTEM EFFECTIVENESS -- DRIVING PARAMETERS

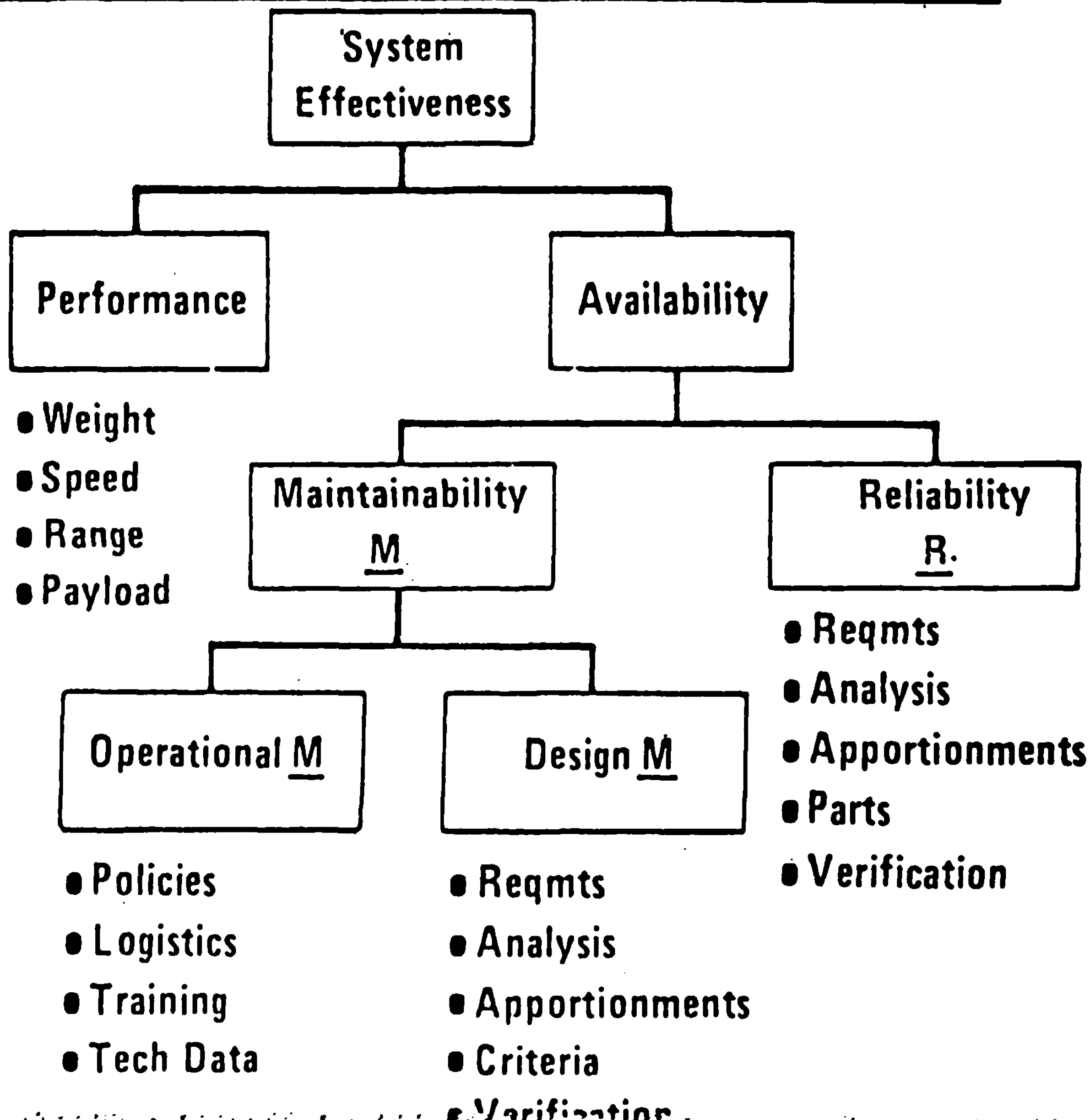


ILLUSTRATION OF COST VERSUS MTBF RESULTING IN DIFFERENT PROBABILITIES OF MISSION SUCCESS

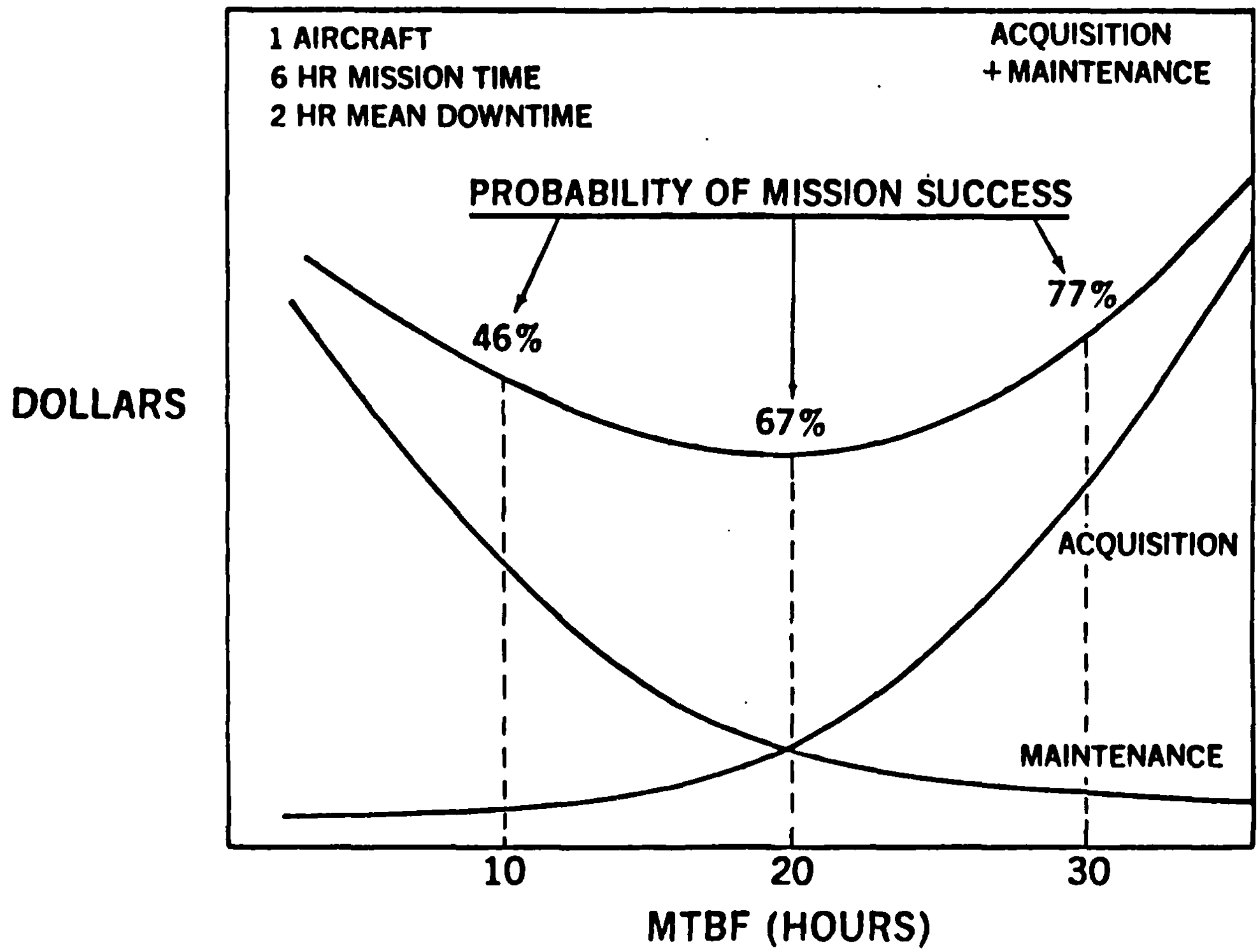


ILLUSTRATION OF PERSONNEL POLICY IMPACT ON THE COST OF MAINTENANCE

CALCULATION OF DIRECT MANPOWER UTILIZED

1. ORGANIZATION MAINTENANCE = NUMBER OF MAINTENANCE ACTIONS PER FLYING HOUR X MEAN TIME TO FAULT ISOLATE, ACCESS AND REPAIR OR REPLACE

$$\text{ORG. MMH/FH} = \frac{UF}{MTBF} \quad PAMH + (RIP)(IMH) + (1 - RIP)(RMH)$$

2. INTERMEDIATE MAINTENANCE MANHOURS PER FLYING HOUR = NUMBER OF REMOVALS PER FLYING HOUR X MEAN TIME TO REPAIR

$$\text{INT. MMH/FH} = \frac{UF}{MTBF} \quad (1 - RIP)(MTTR)$$

PARAMETER	SUBSYSTEM ALTERNATIVE 1	SUBSYSTEM ALTERNATIVE 2
UF	1.25	1.25
MTBF	10 HRS.	15 HRS.
PAMH	.50 HRS.	.75 HRS.
RIP	.20 HRS.	.40
IMH	.25 HRS.	1.50 HRS.
RMH	.75 HRS.	1.0 HRS.
MTTR	2 HRS.	3 HRS.

- CALCULATION OF DIRECT MANPOWER UTILIZED (CONT.)

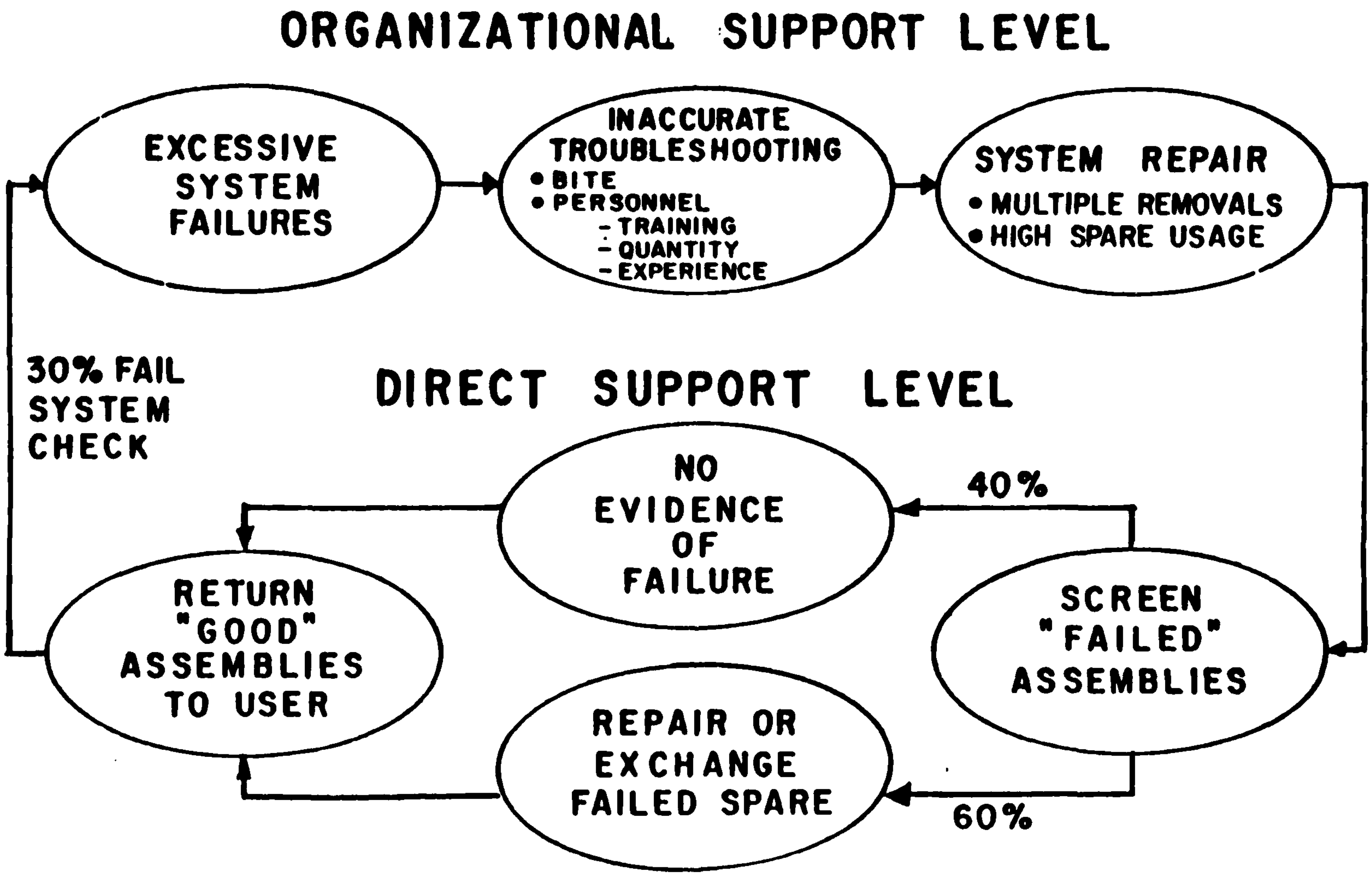
	ALT. 1	ALT. 2	(1) - (2)
ORG. MMH/FH	.144	.162	.010
INT. MMH/FH	.200	.150	.050
TOTAL DIRECT MMH/FH	.344	.312	.032

- EXTRAPOLATE TO TOTAL MAINTENANCE MANNING REQUIRED TO BE AVAILABLE AS A FUNCTION OF DEPLOYMENT NEEDS, MANNING POLICIES, SKILL CRITICALITY, AND FLYING PROGRAM

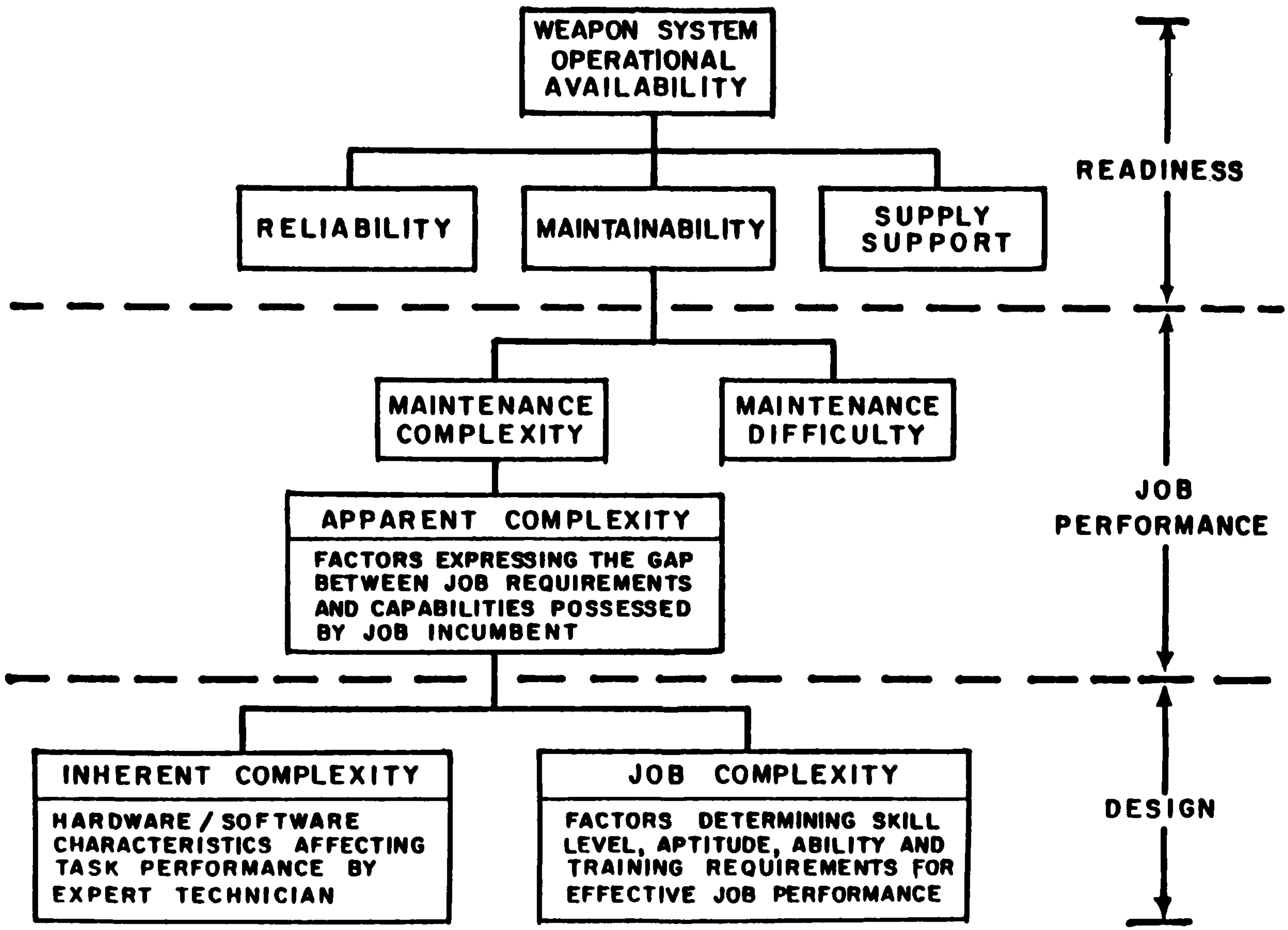
- MAINTENANCE MANNING IMPACT
  - ORGANIZATION MAINT. MANPOWER: NONE
  - INTERMEDIATE MAINT. MANPOWER: ALTERNATIVE 1 REQUIRES THREE ADDITIONAL TECHNICIANS PER WING @ $10,000 PER YEAR EACH

MANIFESTATIONS OF MAINTENANCE COMPLEXITY

(IHAWK EXAMPLE)



FRAMEWORK FOR ANALYSIS OF MAINTENANCE COMPLEXITY



IMPACT OF MAINTENANCE COMPLEXITY

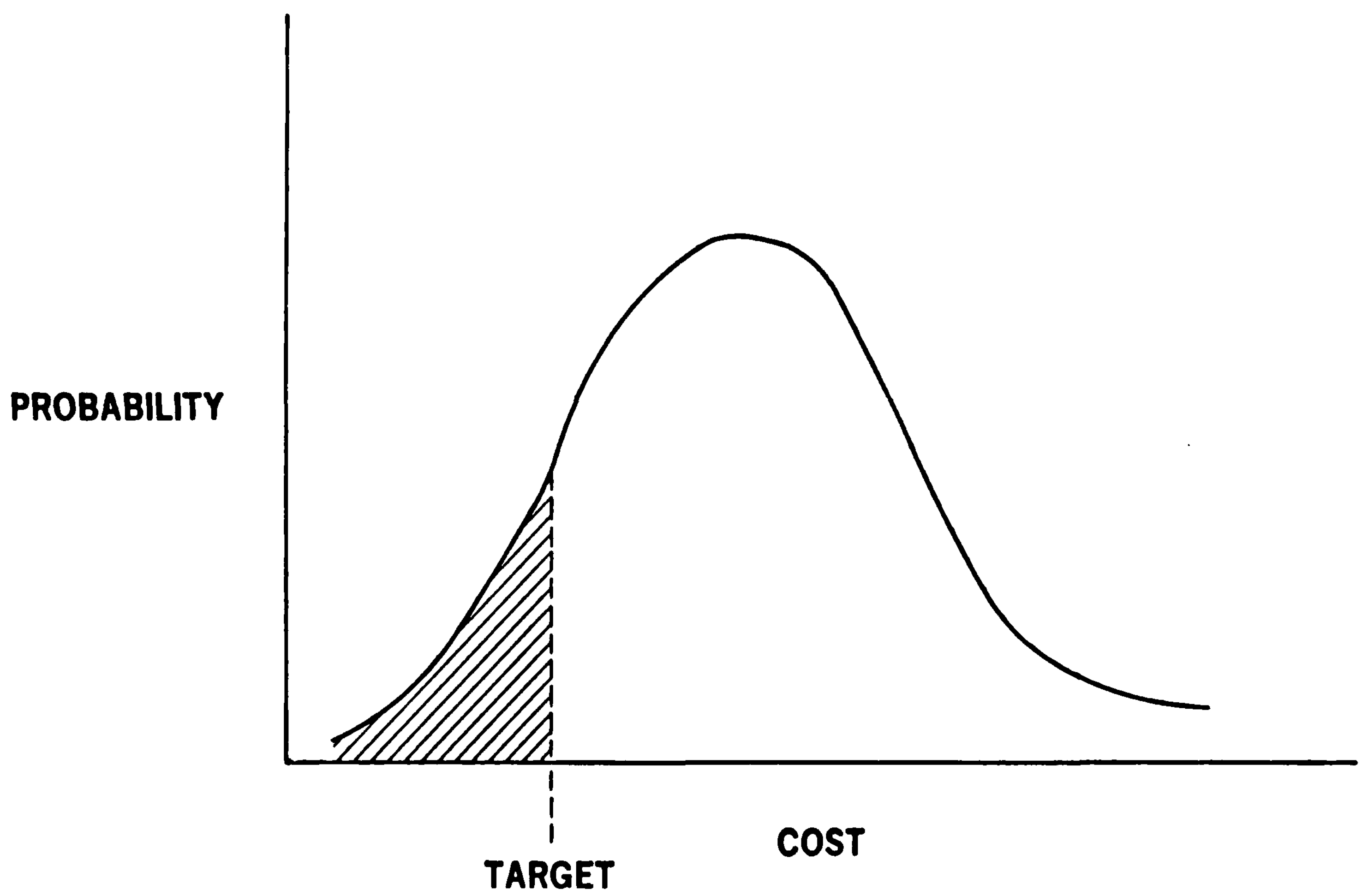
- INCREASED DEMANDS ON THE SUPPLY SYSTEM
- INCREASED MAINTENANCE WORKLOADS
- NEED FOR NON-ORGANIC MAINTENANCE SUPPORT
- UNCERTAIN WARTIME SUSTAINABILITY

SUB-SET #9

STATISTICAL ELEMENTS IN LCCA

LIFE CYCLE COST ANALYSIS: IMPORTANT CONSIDERATIONS

- COST/RISK UNCERTAINTY ANALYSIS


PROBABILITY
TARGET
COST

QUANTIFYING AND PRESENTING UNCERTAINTY IN LIFE-CYCLE COST ESTIMATES

TO IMPROVE DECISION MAKING BY PROVIDING A MEANS TO DISPLAY AND COMMUNICATE COST UNCERTAINTY

FUTURE COSTS SHOULD BE VIEWED IN TERMS OF A RANGE OF POSSIBLE COSTS, AND MANAGEMENT DECISIONS SHOULD BE BASED ON THAT PREMISE

- PLANNING
- REVIEW

SOURCES OF UNCERTAINTY

CHANGES IN SCOPE (PERFORMANCE, QUANTITY, SCHEDULE)

- IN GENERAL NOT ANTICIPATED
- NOT EXPLICITLY HANDLED IN UNCERTAINTY ANALYSIS
- ADJUST BASELINE ESTIMATE TO REFLECT SCOPE ADJUSTMENT

TECHNICAL AND TECHNOLOGICAL PROBLEMS (MATERIAL OR PRODUCTION PROBLEMS, RESOURCE LIMITATIONS, ETC.)

- IN GENERAL NOT ANTICIPATED
- NOT EXPLICITLY HANDLED IN UNCERTAINTY ANALYSIS
- ADJUST BASELINE ESTIMATE TO REFLECT PROBLEM

UNCERTAINTY INHERENT IN THE STATISTICAL ESTIMATING METHOD (OMISSION OF RELEVANT PARAMETERS, MODEL FORM, RANDOM NATURE OF PROCESS BEING MODELED)

- CAN ANALYZE THIS KIND OF UNCERTAINTY

UNCERTAINTY AS A FUNCTION OF THE LIFE CYCLE

SUBOPTIMIZATION UNCERTAINTY

TREATING COST UNCERTAINTY: BASIC STRATEGIES

➡ STATISTICAL ESTIMATING

BOUNDING TECHNIQUES
- A FORTIORI ANALYSIS
- SENSITIVITY ANALYSIS
- BREAKEVEN ANALYSIS

REDUCING UNCERTAINTY
- TESTING
- SPECIAL STUDIES

IGNORING UNCERTAINTY
- WAITING
- POINT ESTIMATES

ESTIMATING UNCERTAINTY

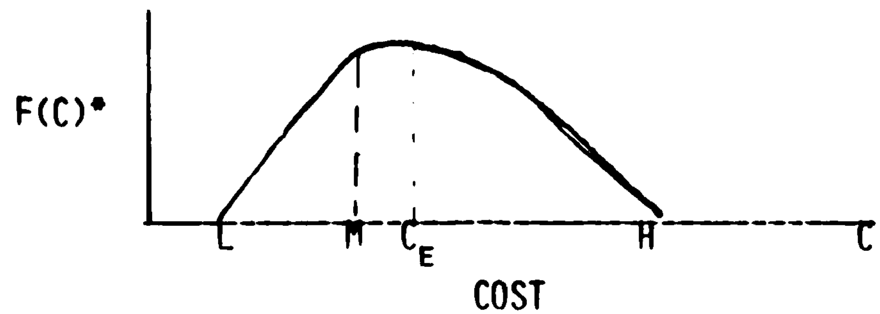
DETERMINING OUTPUT UNCERTAINTY AS A FUNCTION OF INPUT PARAMETER UNCERTAINTIES

- CONVOLUTION OF THE PROBABILITY DENSITY FUNCTION
- THEORY OF ERRORS
- MONTE CARLO METHODS
- LINEARLY SCALED BETA FUNCTIONS INVOLVING FOUR PARAMETER ESTIMATES
- SIMPLIFIED BETA FUNCTIONS INVOLVING THREE PARAMETER ESTIMATES

QUANTIFYING COST UNCERTAINTY: BASIC PREMISES

- UTILIZE AN LCC SETTING
- UNCERTAINTY COMPOUNDS WITH TIME
- EACH COST ESTIMATE CAN BE REPRESENTED IN TERMS OF A RANGE OF ESTIMATES PORTRAYED BY A UNIMODAL DISTRIBUTION WITH SPECIFIABLE UPPER AND LOWER BOUNDS

COST DISTRIBUTION AND PARAMETERS



*FREQUENCY OF OCCURENCE OR PROBABILITY DENSITY.

WHERE:

F(C) - IS A FUNCTION WHICH DEFINES THE PROBABILITY DENSITY FOR EACH VALUE OF C BETWEEN L AND H

L - IS THE UNKNOWN TRUE LOWEST COST TO PRODUCE AN ITEM, OR TO OWN AN ITEM, ETC.

M - IS THE MOST LIKELY COST; I.E., THE MODE

C_E - IS THE TRUE MEAN OR EXPECTED COST; IN THE ABOVE FIGURE C_E IS THE COST SUCH THAT THE AREA UNDER THE CURVE IS EQUALLY DISTRIBUTED ABOUT C_E

H - IS THE UNKNOWN TRUE HIGHEST COST

C - IS THE RANDOM VARIABLE REPRESENTING COST

RELATING THE COST VALUES: L, M, C_E AND H

THE DECISION MAKER PROVIDES ESTIMATES OF M, H AND L

SUPPORTING ANALYSES PROVIDES ESTIMATES FOR M, H AND L

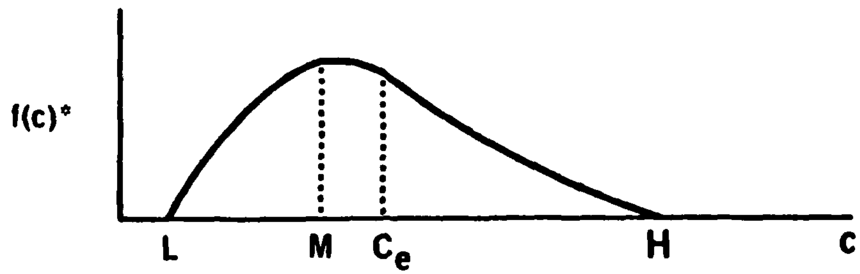
- ENGINEER ESTIMATES
- ANALOGY
- SCALING

CONSIDER THE BETA DISTRIBUTION

- IT IS UNIMODAL
- IT CAN BE SHAPED SUCH THAT M CAN BE CLOSER TO L OR H OR THE YET UNKNOWN MEAN, C_E
- IT IS A FINITE DISTRIBUTION (L AND H BOUND THE ENTIRE RANGE)
- SIMPLE AND STATISTICALLY VALID TECHNIQUES EXIST TO ESTIMATE C_E AND THE VARIANCE OF THE DISTRIBUTION AS A FUNCTION OF M, L AND H

RELATING THE COST VALUES: L, M, C_E AND H

BETA COST DISTRIBUTION AND PARAMETERS



*FREQUENCY OF OCCURRENCE OR PROBABILITY DENSITY.

WHERE:

f(c) — IS A FUNCTION WHICH DEFINES THE PROBABILITY DENSITY FOR EACH VALUE OF C BETWEEN L AND H

FOR THE STANDARDIZED BETA DISTRIBUTION:

$$f(c) = Kx^{\alpha} (1 - x)^{\gamma}$$

WHERE:

$$X = \frac{c - L}{H - L}; \text{ for } 0 < x < 1$$

WHEN:

$$c = M$$

$$x = \frac{\alpha}{\gamma + \alpha} = Z$$

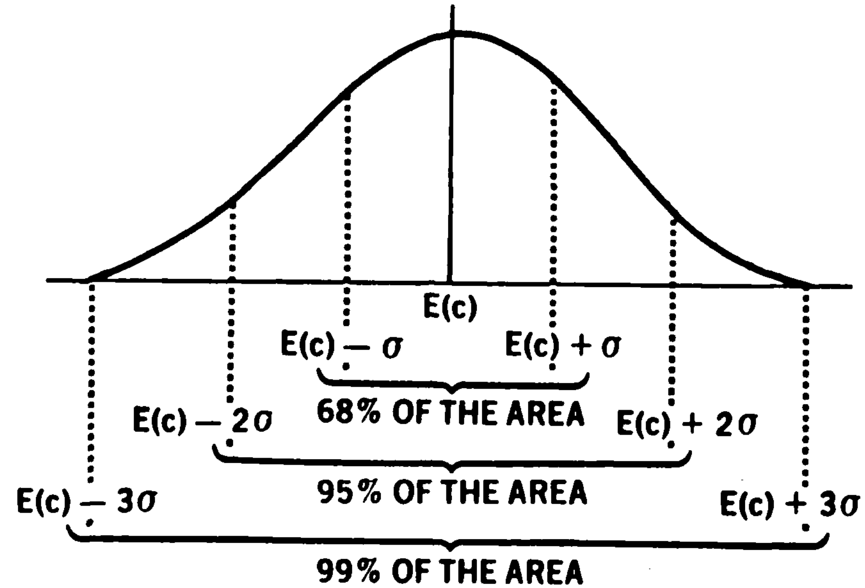
ALSO, THE EXPECTED VALUE:

$$E(c) = \frac{\alpha + 1}{\alpha + \gamma + 2}$$

AND THE VARIANCE (V):

$$V = \frac{(\alpha + 1)(\gamma + 1)}{(\alpha + \gamma + 3)(\alpha + \gamma + 2)^2}$$

BASIC CHARACTERISTICS OF THE NORMAL DISTRIBUTION



IF WE STATE THAT:

$$E(c) \approx L + 3\sigma$$
$$E(c) \approx H - 3\sigma$$

THEN:

$$\sigma \cong \frac{H - L}{6} \quad 1/6$$

OR:

$$V \cong \sigma^2 = \left(\frac{H - L}{6}\right)^2 \approx 1/36$$

WHICH IS THE SIMPLIFIED RELATIONSHIP WE DESIRE

A SIMPLE RELATIONSHIP FOR E(c)

SUBSTITUTING: $Z = \dfrac{a}{\gamma + a}$

AND: $V \approx 1/36$

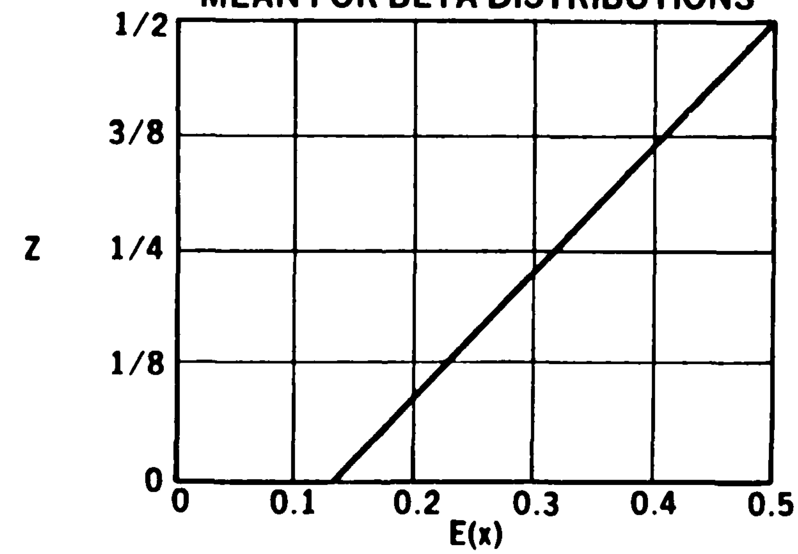
INTO: $V = \dfrac{(a + 1)(\gamma + 1)}{(a + \gamma + 3)(a + \gamma + 2)^2}$

YIELDS A RELATIONSHIP THAT MUST BE SATISFIED:

$$a^3 + (36Z^3 - 36Z^2 + 7Z)\,a^2 - 20Z^2\,a - 24Z^3 = 0$$

FOR VALUES OF a, γ BOTH Z AND E(x) CAN BE ESTIMATED

EMPIRICAL APPROXIMATION FOR ESTIMATING THE MEAN FOR BETA DISTRIBUTIONS



$$E(x) \approx \frac{4Z+1}{6}$$

WHICH LEADS (EVENTUALLY) TO:

$$C_e = \frac{L + 4M + H}{6}$$

GIVEN ESTIMATES OF M, H AND L FOR A COST ELEMENT, WE CAN ESTIMATE ITS MEAN AND VARIANCE:

$$C_e = \frac{L + 4M + H}{6}$$

$$V = \left(\frac{H - L}{6}\right)^2$$

WE NOW NEED TO:

(A) AGGREGATE OVER ALL THE COST ELEMENTS FOR EACH POINT IN TIME

(B) AGGREGATE OVER THE TIME FOR THE LIFE CYCLE

GENERALIZED BETA APPROXIMATION

- CENTRAL TENDENCY (RANGE) ADJUSTMENT

$$\text{MEAN} = \frac{H_{.05} + 0.95M + L_{.05}}{2.95}$$

$$\text{VARIANCE} = \left(\frac{H_{.05} - L_{.05}}{3.25}\right)^2$$

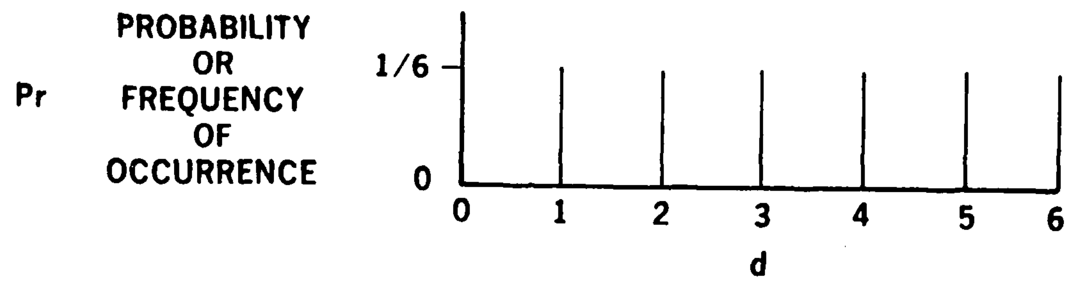
THIS CAN BE DONE IN A STATISTICALLY VALID MANNER BY USING THE CENTRAL LIMIT THEOREM:

IF THE COST ESTIMATES FOR THE INDIVIDUAL COST ELEMENTS ARE INDEPENDENTLY DISTRIBUTED AND HAVE A FINITE VARIANCE AND MEAN, THEN THE SUM OF THE ESTIMATES CAN BE READILY COMPUTED, AND ADDITIONALLY THE DISTRIBUTION OF THE SUM OF THE COSTS APPROACHES THE NORMAL DISTRIBUTION AS THE NUMBER OF COST ESTIMATES INCREASES. THIS THEOREM HOLDS REGARDLESS OF THE TYPE OF DISTRIBUTION FOR THE INDIVIDUAL COST ELEMENTS.

A SIMPLE ILLUSTRATION OF THE CENTRAL LIMIT THEOREM

A COST ELEMENT REPRESENTED BY A FAIR DIE

UNIFORM OR RECTANGULAR DISTRIBUTION FOR A SINGLE DIE



WITH:

$$\text{MEAN} = 1(1/6) + 2(1/6) + 3(1/6) + 4(1/6) + 5(1/6) + 6(1/6)$$

$$= 3\text{-}1/2$$

AND, VARIANCE:

$$V = \left[(d_i - \text{MEAN})^2\right] Pr_{(d)}$$

$$= \left[(1 - 3\text{-}1/2)^2\right] 1/6 + \left[(2 - 3\text{-}1/2)^2\right] 1/6 + \ldots + (6 - 3\text{-}1/2)^2\Big] 1/6$$

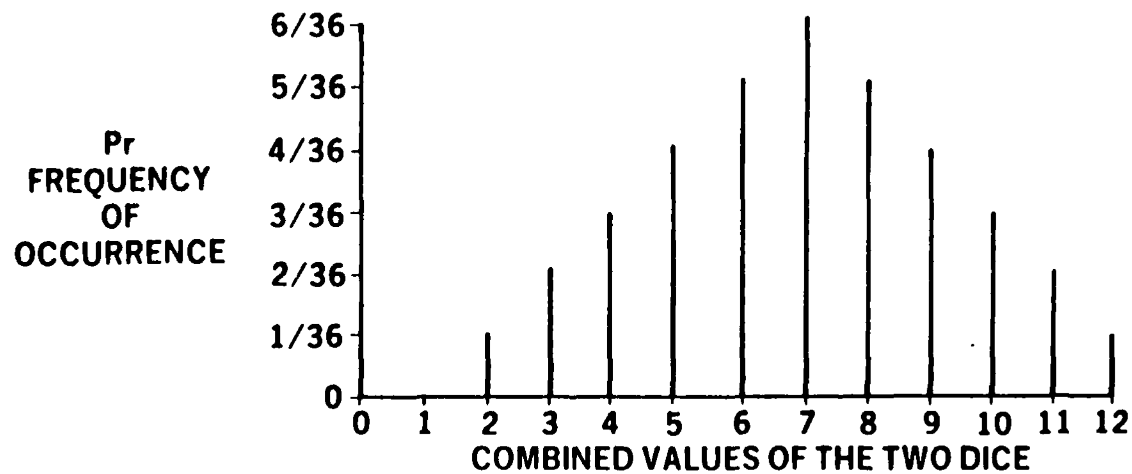
$$= 2\text{-}11/12$$

TWO COST ELEMENTS REPRESENTED BY TWO FAIR DICE

MATRIX OF VALUES FOR TWO DICE

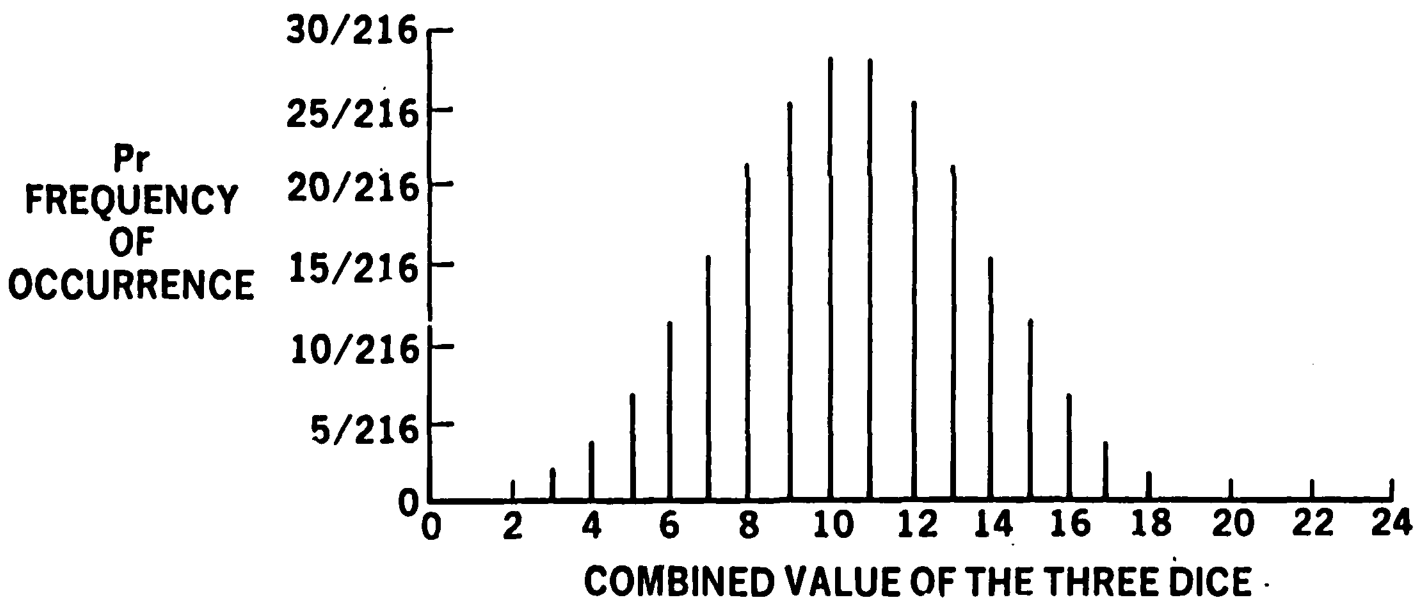
DIE TWO \ DIE ONE	1	2	3	4	5	6
1	2	3	4	5	6	7
2	3	4	5	6	7	8
3	4	5	6	7	8	9
4	5	6	7	8	9	10
5	6	7	8	9	10	11
6	7	8	9	10	11	12

DISTRIBUTION OF THE COMBINED VALUES FOR TWO DICE



THREE COST ELEMENTS REPRESENTED BY THREE FAIR DICE

DISTRIBUTION OF THE COMBINED VALUES OF THE THREE DICE



USING THE CENTRAL LIMIT THEOREM ALLOWS THE USE OF THE PROPERTIES OF THE NORMAL DISTRIBUTION FOR THE AGGREGATE CASE

— SUMMING COSTS WITHIN A YEAR

— SUMMING COSTS OVER THE LIFE CYCLE

— ESTIMATING THE CONFIDENCE (UNCERTAINTY) BAND FOR THE AGGREGATE COST ESTIMATES

BASIC PROCEDURE

1. ESTIMATE M, L AND H FOR EACH COST ELEMENT
2. ESTIMATE THE MEAN AND VARIANCE FOR EACH COST ELEMENT (BETA APPROXIMATIONS)
3. SUM THE MEANS, VARIANCES AND MODES OVER ALL THE COST ELEMENTS FOR YEARLY TOTALS
4. COMPUTE THE STANDARD DEVIATION FOR EACH YEARLY TOTAL
5. ESTABLISH A CONFIDENCE BAND FROM THE STANDARD NORMAL TABLES: REPRESENTED AS A MULTIPLE OF THE STANDARD DEVIATION
6. PLOT THE MODES AND THE MEANS ± A MULTIPLE OF THE STANDARD DEVIATION

ILLUSTRATION

- HYPOTHETIC AIRCRAFT DEPLOYABLE UNIT
- MILESTONE II
- OPERATING AND SUPPORT COST ESTIMATES

O&S COST ESTIMATES FOR A HYPOTHETIC AIRCRAFT DEPLOYABLE UNIT FOR YEAR 4 IN ITS LIFE CYCLE

(MILLIONS OF FY 77 DOLLARS)

O&S COST ELEMENT*		MOST LIKELY ESTIMATE
301	DEPLOYED UNIT OPERATIONS	8.95
302	BELOW DEPOT MAINTENANCE	5.50
303	INSTALLATIONS SUPPORT	1.35
304	DEPOT MAINTENANCE	4.90
307	PERSONNEL SUPPORT	2.00
308	SUSTAINING INVESTMENTS	5.65
	TOTAL	28.35
	UNCERTAINTY RANGE (90% CONFIDENCE INTERVAL)	(+7.8% / −1.1%)

*NOTE THAT COST ELEMENTS 305 AND 306 ARE NOT ASSIGNED TO DEPLOYABLE UNITS.

STEP 1

FOR EACH COST ELEMENT DETERMINE THE MOST LIKELY VALUE (M), THE LOWEST VALUE (L) AND THE HIGHEST VALUE (H), FOR EACH YEAR

COST ELEMENT 302 — BELOW DEPOT MAINTENANCE
FOR YEAR 4 IN MILLIONS OF 1977 DOLLARS

M	L	H
5.5	5.0	7.5

STEP 2

COMPUTE THE MEAN AND VARIANCE (V) FOR EACH COST ELEMENT FOR EACH YEAR

$$\text{MEAN} = \frac{L + 4M + H}{6} = \frac{5.0 + (4)(5.5) + 7.5}{6} = \$5.75 \text{ MILLION}$$

$$\text{VARIANCE} = \left(\frac{H - L}{6}\right)^2 = \left(\frac{7.5 - 5.0}{6}\right)^2 = 0.17(\times 10^{12} \text{ in } \$^2)$$

STEP 3

SUM THE MEAN, MODE AND VARIANCE ESTIMATES (FOR A HYPOTHETIC AIRCRAFT DEPLOYABLE UNIT OPERATING AND SUPPORT COSTS FOR YEAR 4)

(MILLIONS OF FY 77 DOLLARS)

COST ELEMENT			MEAN	MODE	VARIANCE
301	DEPLOYED UNIT OPERATIONS				
	301.1	CREW	3.23	3.1	0.11
	301.2	COMMAND STAFF	0.53	0.50	0.003
	301.3	POL	5.44	5.35	0.09
302	BELOW DEPOT MAINTENANCE		5.75	5.5	0.17
303	INSTALLATIONS SUPPORT		1.43	1.35	0.02
304	DEPOT MAINTENANCE		4.96	4.9	0.09
307	PERSONNEL SUPPORT		2.1	2.0	0.04
308	SUSTAINING INVESTMENTS				
	308.1	REPLENISHMENT SPARES	3.18	3.1	0.03
	308.2	MOD KITS AND MATERIAL	1.26	1.2	0.02
	308.3	GSE	0.53	0.5	0.004
	308.4	TRAINING ORDNANCE AND MATERIAL	0.89	0.85	0.005
		TOTAL	29.3	28.35	0.582

STEP 4

COMPUTE THE STANDARD DEVIATION FOR EACH YEAR'S COST ESTIMATE

STANDARD DEVIATION = (FOR YEAR 4 FROM TABLE 3)

$$= (\text{VARIANCE})^{1/2}$$

$$= (0.582)^{1/2}$$

$$= 0.762 \text{ (MILLIONS OF \$)}$$

STEP 5

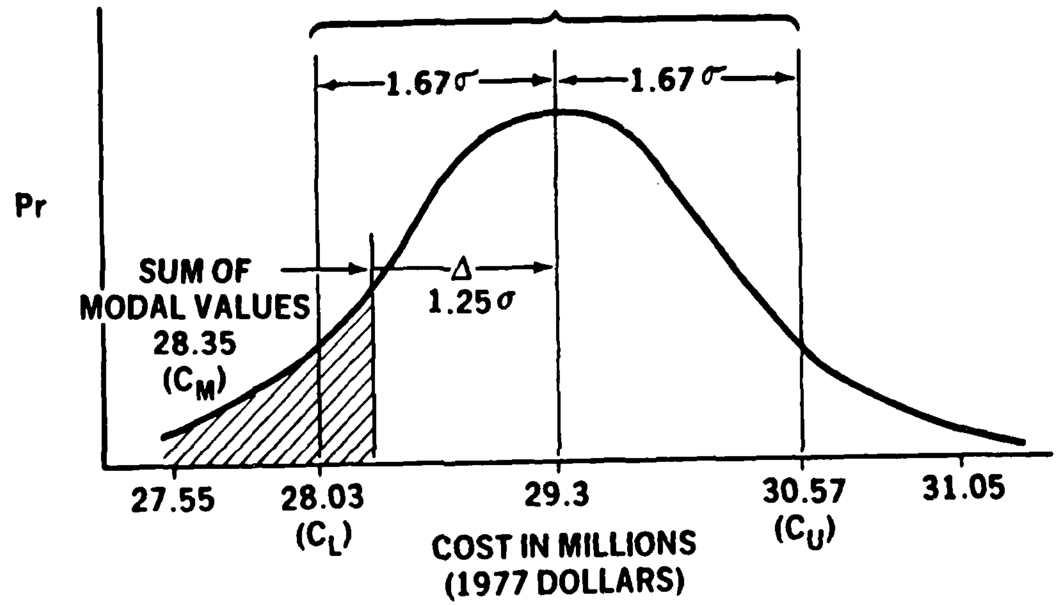
SELECT THE CONFIDENCE FACTOR AND THEN DETERMINE THE UNCERTAINTY RANGE FOR EACH YEAR, FOR A 90-PERCENT CONFIDENCE FACTOR:

- UPPER BOUND OF THE RANGE $= \text{MEAN} + (1.67)(\sigma)$
  $= \$29.3\text{M} + 1.67(\$0.762\text{M})$
  $= \$30.57\text{M}$

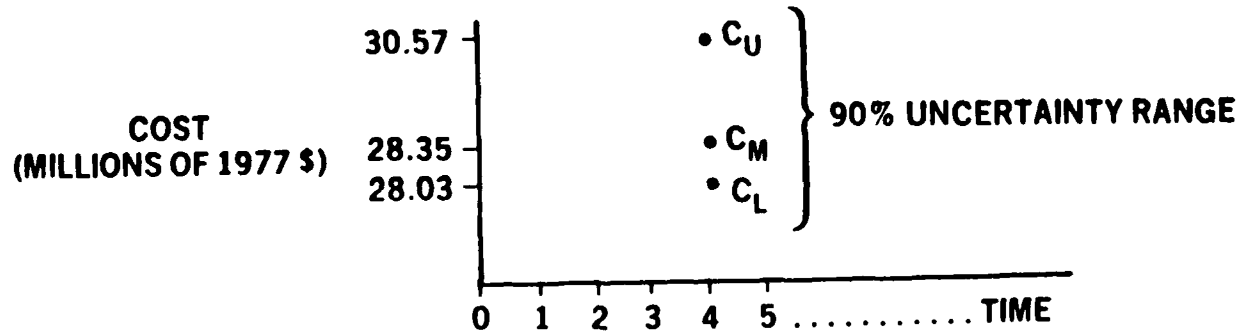
- LOWER BOUND OF THE RANGE $= \text{MEAN} - (1.67)(\sigma)$
  $= \$29.3\text{M} - 1.67(\$0.762\text{M})$
  $= \$28.03\text{M}$

STEP 6

DISTRIBUTION FOR THE COST ESTIMATE FOR YEAR 4



COST VERSUS TIME DISPLAY OF COST ESTIMATES



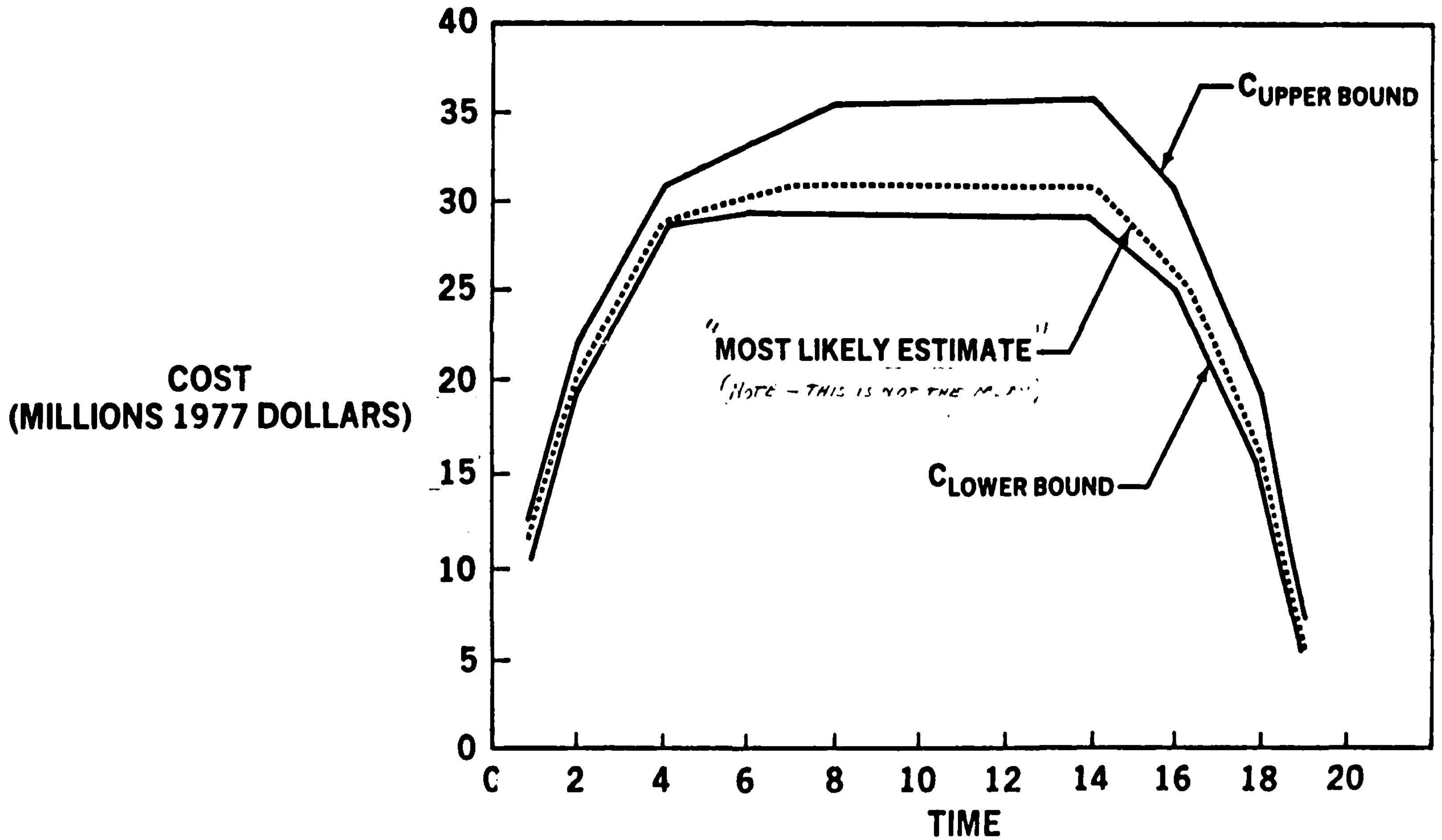
OPERATING AND SUPPORT COST TABULATION FOR HYPOTHETIC AIRCRAFT DEPLOYABLE UNIT

(IN CONSTANT 1977 MILLIONS OF DOLLARS)

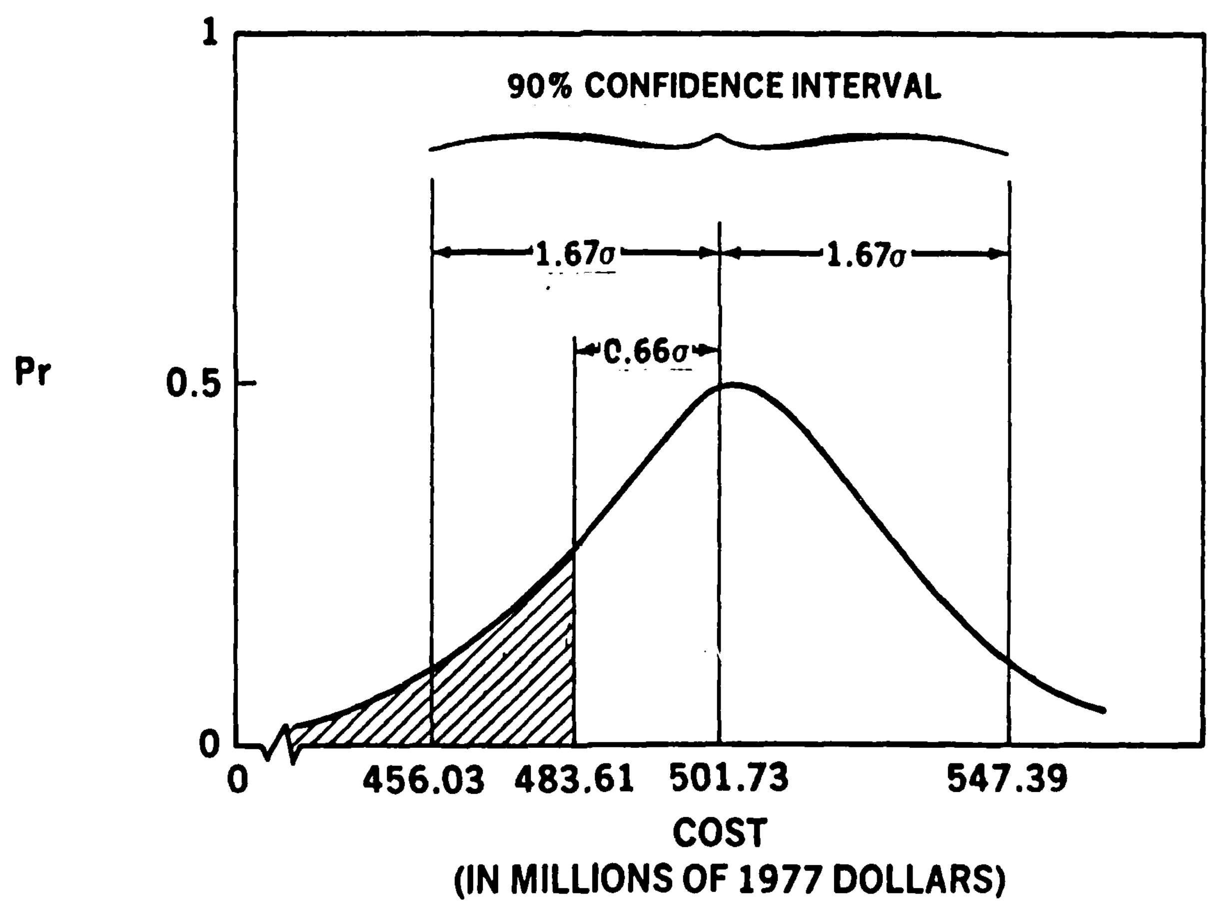
YEAR	COST CATEGORY AND ACTIVITY	SUM OF MODAL ESTIMATE (C_M)	MEAN	90% RANGE		MEAN – C_M (IN σ'S)	UNCERTAINTY RANGE ABOUT C_M (%)
				UPPER BOUND (C_U)	LOWER BOUND (C_L)		
1	O&S, FLEET BUILDUP	10.63	10.84	11.16	10.52	1.11	+5 , –1
2	O&S, FLEET BUILDUP	19.27	19.65	20.23	19.07	1.08	+5 , –1
3	O&S, FLEET BUILDUP	24.44	24.93	25.66	24.19	1.11	+5 , –1
4	O&S, FLEET BUILDUP	28.35	29.30	30.57	28.03	1.25	+7.8 , –1.1
5	O&S, FLEET BUILDUP	28.51	29.22	31.07	27.37	0.65	+9 , –4
6	O&S, STEADY STATE	29.73	30.60	32.70	28.50	0.69	+10 , –4
7	O&S, STEADY STATE	30.61	31.68	34.28	29.07	0.68	+12 , –5
8	O&S, STEADY STATE	30.61	31.68	35.20	28.16	0.51	+15 , –8
9	O&S, STEADY STATE	30.61	31.68	35.20	28.16	0.51	+15 , –8
10	O&S, STEADY STATE	30.61	31.68	35.20	28.16	0.51	+15 , –8
11	O&S, STEADY STATE	30.61	31.68	35.20	28.16	0.51	+15 , –8
12	O&S, STEADY STATE	30.61	31.68	35.20	28.16	0.51	+15 , –8
13	O&S, STEADY STATE	30.61	31.68	35.20	28.16	0.51	+15 , –8
14	O&S, STEADY STATE	30.61	31.68	35.20	28.16	0.51	+15 , –8
15	O&S, STEADY STATE	30.61	31.68	35.20	28.16	0.51	+15 , –8
16	O&S, RETIRE FLEET	25.47	26.63	30.05	23.20	0.57	+18 , –9
17	O&S, RETIRE FLEET	20.16	22.08	24.19	19.96	1.51	+20 , –10
18	O&S, RETIRE FLEET	15.93	17.44	19.12	15.77	1.51	+20 , –10
19	O&S, RETIRE FLEET	5.63	5.92	6.76	5.07	0.57	+20 , –10
	O&S COST TOTAL	483.61	501.73	547.39	456.03	0.66	+13.2 , –6

O&S COST ESTIMATE AND UNCERTAINTY VERSUS TIME

FOR A HYPOTHETIC AIRCRAFT DEPLOYABLE UNIT



TOTAL PROBABLE O&S COST DISTRIBUTION



SENSITIVITY ANALYSIS

A. FOR EACH PARAMETER, IDENTIFY THE RANGE THAT BOUNDS ITS LIKELY VALUE

B. EVALUATE THE COST RELATIONSHIP AT THE EXTREME VALUES OF THE PARAMETER, WITH ALL THE OTHER PARAMETERS AT THEIR MEAN VALUES

C. ASSESS THE SENSITIVITY OF THE COST TO THE DIFFERENT VALUES OF THE PARAMETERS; COMPUTE THE PERCENT CHANGE OR ELASTICITY

D. REPEAT STEPS A-C FOR ALL SIGNIFICANT PARAMETERS <u>AND</u> MAJOR ASSUMPTIONS

DETERMINING THE "AGGREGATE" COST-BENEFIT UNCERTAINTY

USING ERROR THEORY

A. FOR THE LINEAR MODEL CASE, WHERE

COST $(C) = C_1 + C_2 + C_3 + \ . \ . \ .$

<u>MEAN VALUE OF C</u>: $\bar{C} = \bar{C}_1 + \bar{C}_2 + \bar{C}_3 + \ . \ . \ .$

<u>VARIANCE OF C</u>: $VAR(C) = VAR)C_1) + VAR(C_2) + VAR(C_3) \ . \ . \ .$

B. FOR THE PRODUCT RELATIONSHIP

COST $(C) + (X_1)(X_2)(X_3)(X_4)$

<u>MEAN VALUE OF C</u>: $\bar{C} = (\bar{X}_1)(\bar{X}_2)(\bar{X}_3)(\bar{X}_4)$

<u>VARIANCE OF C</u>: $VAR(C) = \sum_{i=1}^{N} \left(\frac{\partial C}{\partial X_i} \right)^2 VAR(X_i)$

FOR: - INDEPENDENT X_i

$$\left(\frac{\partial C}{\partial X_i} \right)^2 \quad >> \quad VAR(X_i)$$

THEORY OF ERROR

FOR A SIMPLE FACTOR MODEL WITH FOUR VARIABLES,

$C = X_1 X_2 X_3 X_4$

THE $\frac{\partial C}{\partial X_i}$ FOR = 1, 2, 3, 4, ARE:

$$\frac{\partial C}{\partial X_1} = X_2 X_3 X_4$$

$$\frac{\partial C}{\partial X_2} = X_1 X_3 X_4$$

$$\frac{\partial C}{\partial X_3} = X_1 X_2 X_4$$

$$\frac{\partial C}{\partial X_4} = X_1 X_2 X_3$$

(ALL THESE VARIABLES ARE EVALUATED AT THEIR MEAN VALUES TO DETERMINE THE VAR(C).)

THEREFORE,

$$\text{VAR}(C) = (X_2 X_3 X_4)^2 \text{ VAR}(X_1) + (X_1 X_3 X_4)^2 \text{ VAR}(X_2) + (X_1 X_2 X_4)^2 \text{ VAR}(X_3) + (X_1 X_2 X_3)^2 \text{ VAR}(X_4)$$

$$+ 2 \sum_{i=1}^{3} \sum_{j=2}^{4} \left(\frac{\partial C}{\partial X_i}\right) \left(\frac{\partial C}{\partial X_j}\right) \sigma_{X_i X_j}$$ THAT ARE SIGNIFICANT

COST UNCERTAINTY AS A FUNCTION OF INPUT PARAMETER UNCERTAINTIES

- REPLENISHMENT AIRFRAME AND ENGINE SPARES COSTS
- FOR ARMY HELICOPTERS
- UNCERTAINTY DUE TO MEAN TIME BETWEEN REMOVAL (MTBR) ESTIMATE UNCERTAINTY

$$CRS = \frac{1}{PDC} \sum_{I} \left[\frac{\left(W_I \times C_{NEW_I} + (1-W_I) C_{OVHL_I}\right) QPA_I}{MTBR_I} \right] (N_{AC})\ (TFHA)\ (Y)$$

WHERE:

C_{RS} = LIFE CYCLE COST OF AIRFRAME AND ENGINE REPLENISHMENT SPARES
I = SUBSCRIPT; FOR EACH DYNAMIC COMPONENT
PDC = PERCENT OF COST REPRESENTED BY DYNAMIC COMPONENTS
W = WASHOUT (CONDEMNATION) RATE
C_{NEW} = COST OF A NEW SPARE
C_{OVHL} = COST OF PARTS AND LABOR TO OVERHAUL A DYNAMIC COMPONENT
QPA = QUANTITY PER AIRCRAFT
MTBR = MEAN TIME BETWEEN REMOVALS
NAC = NUMBER OF AIRCRAFT IN THE FLEET
TFFH = TOTAL FLEET FLYING HOURS PER YEAR
Y = NUMBER OF YEARS OF OPERATION

REPLENISHMENT SPARES - DEMAND DRIVEN UNCERTAINTY

REDUCED FORM EQUATION

$$C_{RS} = \frac{1}{PDC} \sum_{I} C_{RS_I}$$

WHERE:

$$C_{RS_I} = \frac{K_I}{MTBR_I} = K_I \lambda_I$$

WHERE:

K_I = COMBINED VARIABLES HELD CONSTANT

$= (W_I C_{NEW_I} + (1-W_I) C_{OVHL_I}) OPA_I$

λ_I = FAILURE OR REMOVAL RATE FOR COMPONENT I

REPLENISHMENT SPARES - DEMAND DRIVEN UNCERTAINTY

FOR INDEPENDENT FAILURES OF THE DYNAMIC COMPONENTS

- COMPONENT MEAN COST: $\bar{C}_{RS_I} = K_I \bar{\lambda}_I$
- AGGREGATE MEAN COSTS: $\bar{C}_{RS} = \left(\sum_I K_I \quad _I\right) \frac{1}{PDC}$
- COMPONENT COST VARIANCE: $VAR(C_{RS_I}) = K_I \; VAR(\lambda_I)$
- AGGREGATE COST VARIANCE: $VAR(C_{RS}) = \sum K_I \; VAR(\lambda_I)$

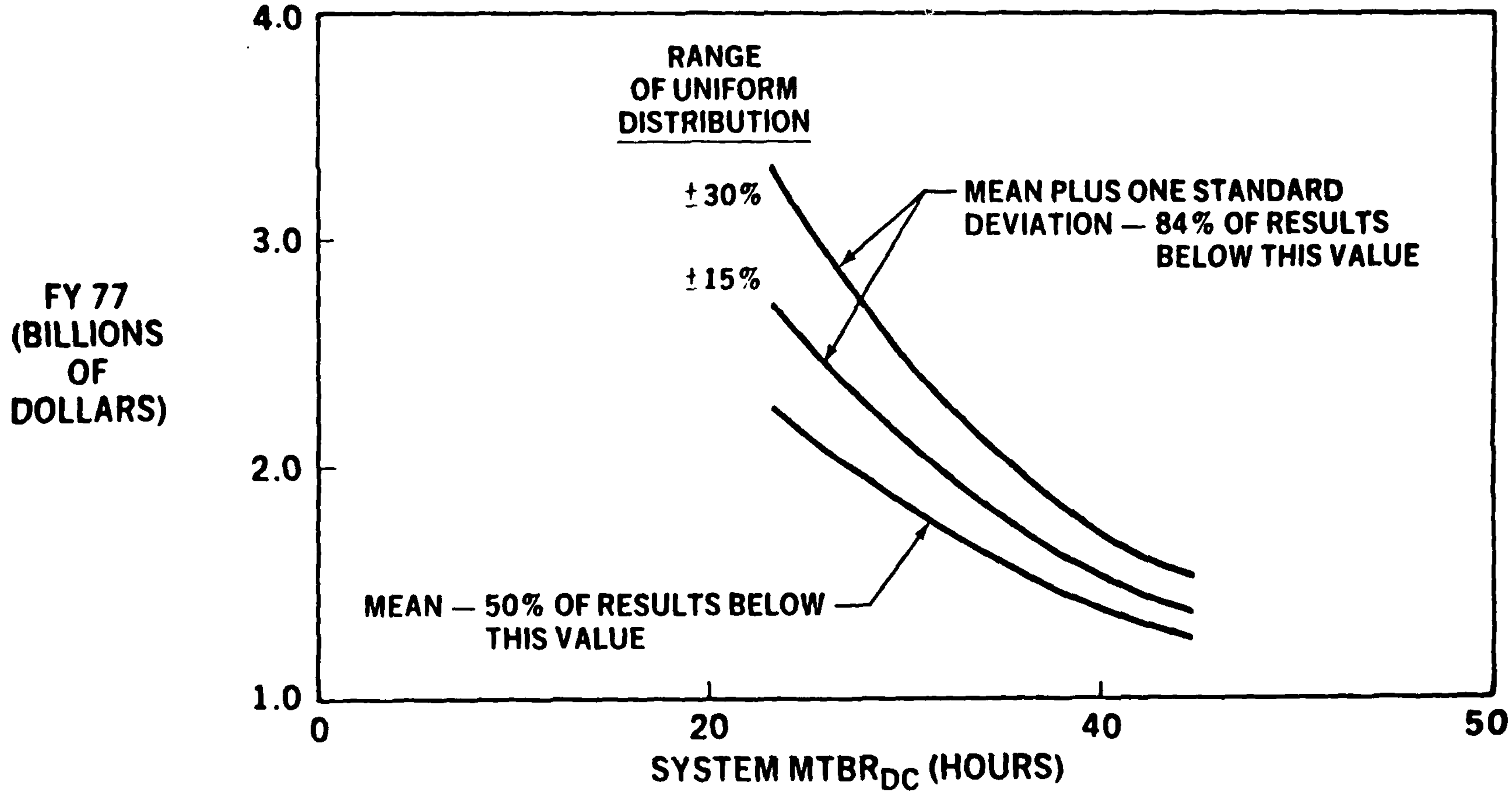
ASSUME: THE λ_I'S ARE INDEPENDENT, AND ARE UNIFORMALLY DISTRIBUTED BETWEEN λ_I(LOW) AND λ_I(HIGH). THEN WE USE THE CENTRAL LIMIT [redacted] THEOREM TO ESTABLISH THE CONFIDENCE BANDS FOR THE AGGREGATE MEAN AND VARIANCE (OR ITS SQUARE ROOT THE STANDARD DEVIATION ( )

$\pm 1\sigma$ FOR $\sim$ 68% CONFIDENCE FACTOR

$+ 1\sigma$ FOR $\sim$ 84% CONFIDENCE FACTOR

REPLENISHMENT SPARES DEMAND DRIVEN UNCERTAINTY

EACH COMPONENT MTBR UNIFORMLY DISTRIBUTED AROUND ARMY ESTIMATE



SUB-SET #10

LCCA CORRECTION FACTORS

LIFE CYCLE COST ANALYSIS: IMPORTANT CONSIDERATIONS

- ADJUSTING COST ESTIMATES

ECONOMIC ANALYSIS OF CASH FLOWS

- Capital and life cycle cost/benefit evaluation
- Time value of money
- Risk
- Inflation
- Discounting - applications and limitations

CASH FLOW ECONOMIC ANALYSIS - OBJECTIVES

- TO MEASURE THE PRODUCTIVITY OF EXPENDITURES OVER TIME AGAINST THE BENEFITS DERIVED FROM THOSE EXPENDITURES
- EFFECTIVE DECISION MAKING

PREMISES

- FUTURE DOLLARS (MONEY) ARE WORTH LESS THAN TODAY'S DOLLARS
  - MONEY HAS VALUE RELATED TO THE TIMING OF ITS RECEIPTS AND DISBURSEMENTS
  - VALUE IS DETERMINED BY THE OPPORTUNITY TO EARN FROM NORMAL INVESTMENT ACTIVITY (MINIMUM AVAILABLE RATE OF RETURN)
  - THE OPPORTUNITY COST IS THE PREVAILING INTEREST RATE OR THE OPPORTUNITY RATE OF RETURN FOR THE MOST EFFECTIVE PROJECT AVAILABLE

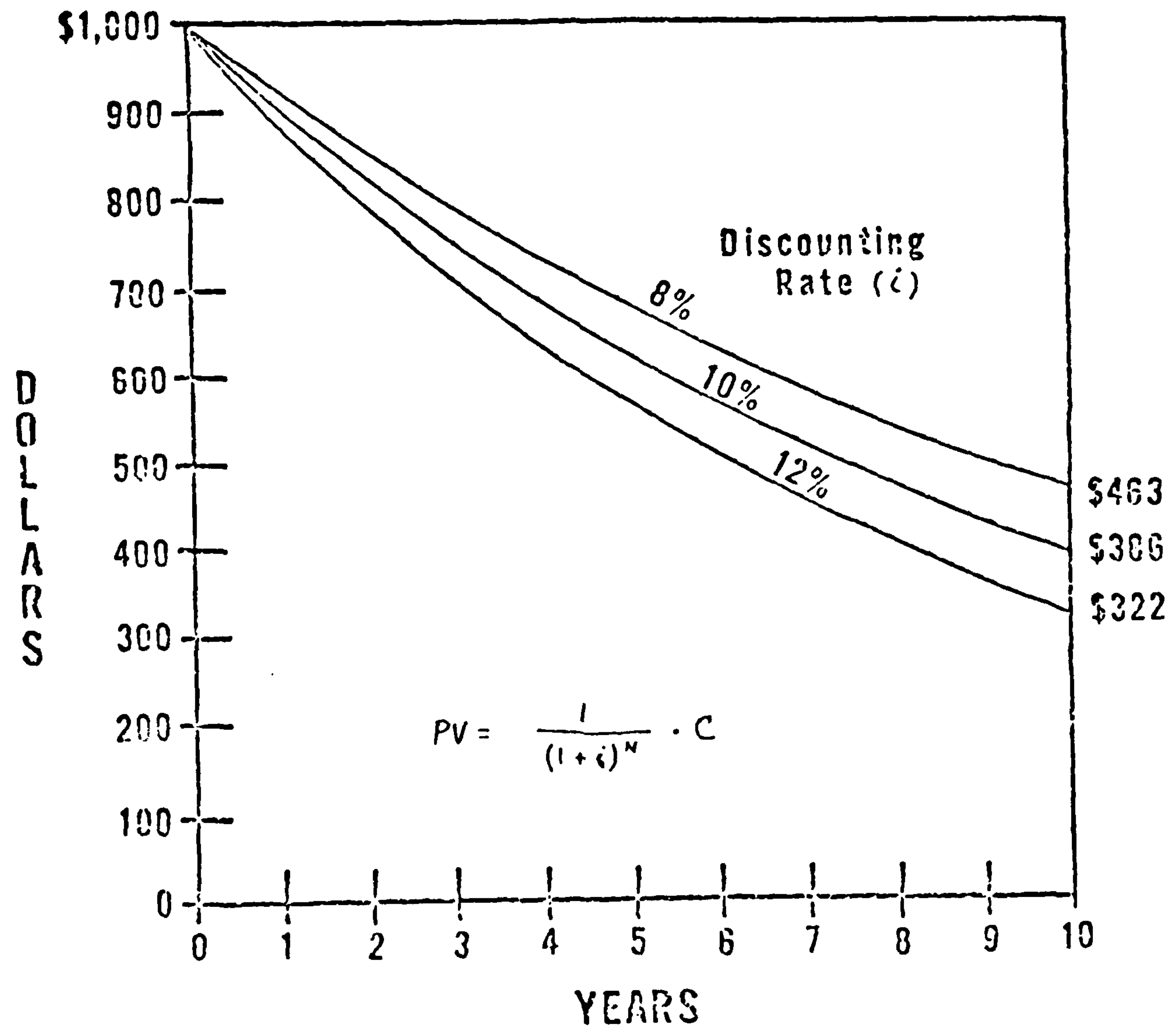
DISCOUNTING

- THE ADJUSTMENT OF CASH FLOW RECEIPTS AND DISBURSEMENTS TO REFLECT THE TIME VALUE OF MONEY
- BASED ON THE CONSIDERATION OF COMPOUND INTEREST
- REFLECTS ECONOMIC OR FINANCIAL RISK NOT REQUIREMENTS UNCERTAINTY
- DISTINCT FROM INFLATION

PRESENT VALUE

- A MEASURE IN TODAY'S DOLLARS OF FUTURE CASH FLOWS
- NORMALIZED DOLLARS - AN EQUIVALENT BASIS

PRESENT VALUE



LCC: DISCOUNTING

- CONCEPT
  - THE TIME VALUE OF MONEY

$$\frac{C_N}{(1 + I)^N}$$

  - NORMALIZES DIFFERENT CASH FLOWS
  - PRESENT VALUE (PV)

- ILLUSTRATION

$N = 1, 2, 3$

$C_N = \$100$

$I = 10\%$

$$PV = \frac{C_N}{(1 + I)^N}$$

$$= \frac{100}{1.1} + \frac{100}{1.21} + \frac{100}{1.31}$$

$$= \$248.69$$

CASH FLOW DIAGRAMS

- A TIME CHART SHOWING POSITIVE AND NEGATIVE CASH FLOWS AT THE TIME THEY ARE PLANNED TO OCCUR IN THE PROJECT PLAN

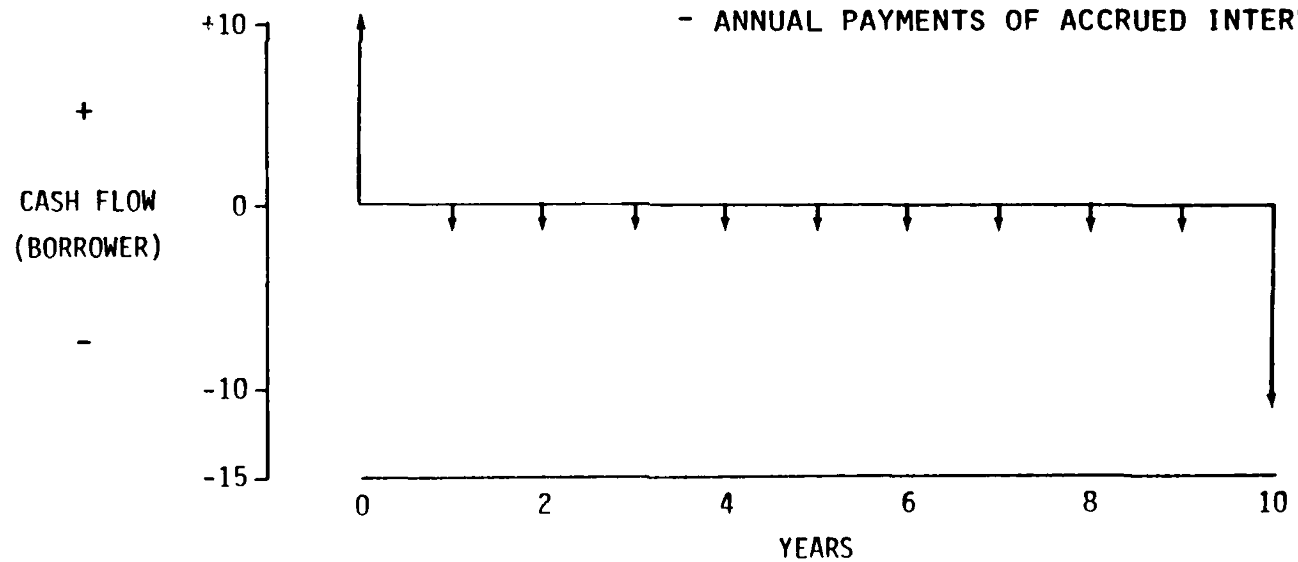
- EXAMPLE: A BANK LOAN

  PRINCIPAL - $10,000

  INTEREST - 10%

  TERMS - 10-YEAR LOAN

  - BALLOON PAYMENT OF PRINCIPAL
  - ANNUAL PAYMENTS OF ACCRUED INTEREST



APPROPRIATE CONDITIONS FOR DISCOUNTING

- MONEY CAN BE TRANSFERRED ACROSS PROJECTS
- MONEY AVAILABLE (IN-HAND) THAT IS NOT SPENT/INVESTED IS NOT LOST OR GIVEN UP. POSTPONING AN EXPENDITURE DOES NOT MEAN LOSING THE MONEY
- MONEY REPRESENTS AN EQUIVALENT MEASURE OF EFFECTIVENESS FOR ALL INVESTMENT OPPORTUNITIES
- ACHIEVE A REQUIRED EFFECTIVENESS AT THE MINIMUM COST

CONSEQUENCES OF DISCOUNTING

- DISCOUNTING WILL CAUSE PROJECTS WITH DEFERRED RETURNS TO BE AVOIDED
- DISCOUNTING WILL CAUSE PROJECTS WITH DEFERRED COSTS TO BE FAVORED

CONDITIONS WHEN DISCOUNTING MAY <u>NOT</u> BE APPROPRIATE

- DECENTRALIZED CONTROL THROUGH FISCAL CONSTRAINTS
- MAXIMIZING EFFECTIVENESS FOR FIXED (CURRENT AND FUTURE) BUDGET LEVELS (CONSTRAINTS)
  - DECIDE ON HOW MUCH CAN BE SPENT FIRST AND THEN BUY THE BEST POSSIBLE SYSTEM FOR THE AVAILABLE FUNDS
- LIMITED OR NO TRANSFERABILITY OF FUNDS ACROSS PROJECTS
  - FUNDS NOT SPENT ARE GIVEN BACK
- DIFFERENT LEVELS OR TYPES OF EFFECTIVENESS ARE NOT READILY COMPARED IN TERMS OF DOLLARS

HYPOTHETIC 15 YEAR LIFE CYCLE COST IN 1973 DOLLARS

- ACQUISITION
  - AIRFRAME 38%
  - ENGINE 13%
  - PECULIAR EQUIPMENT AND SPARES 20%
  - ELECTRONICS 13%
  - OTHER 16%

	DISCOUNT RATE
$4.2 MILLION/UNIT -	0%
$5.2 MILLION/UNIT -	5%
$6.4 MILLION/UNIT -	10%

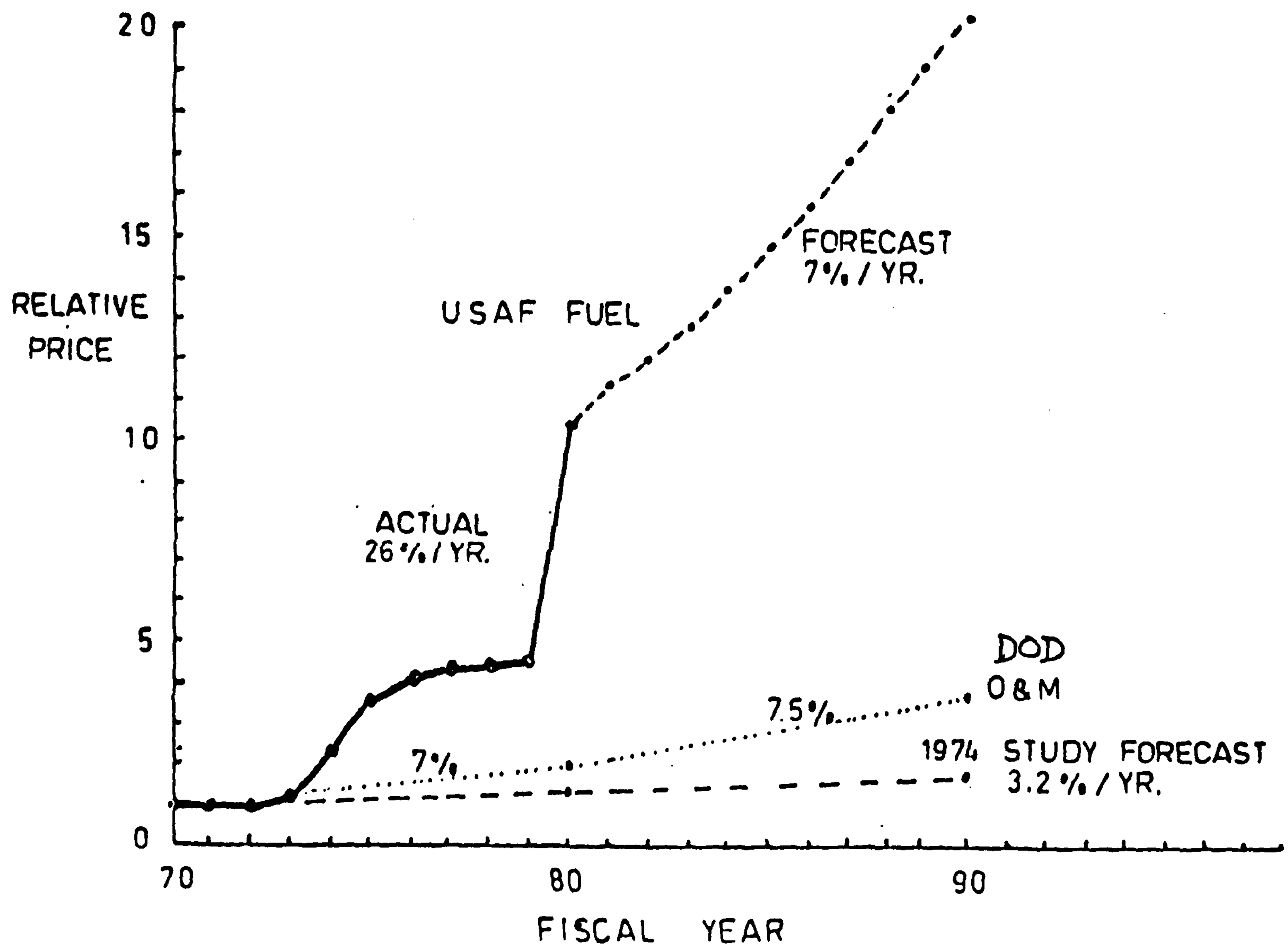
- OWNERSHIP
  - OPERATIONS AND MAINTENANCE 48%
  - INVESTMENT 15%
  - DEPOT 16%
  - BASE OPERATING SUPPORT 10%
  - FUEL 4%
  - TRAINING 7%

$8.7 MILLION/UNIT -	0%
$6.8 MILLION/UNIT -	5%
$4.7 MILLION/UNIT -	10%

ADJUSTING FOR INFLATION

- Loss in purchasing value
- General rates/indices
- Differential escalation factors

FUEL COST VARIABILITY



RELATIVE INFLATIONARY IMPACTS

(DIFFERENTIAL ESCALATION RATES)

- THE DIFFERENCE BETWEEN THE GENERAL RATE OF INFLATION AND THE RATE ANY ONE DOMINANT PARAMETER (E.G., ENERGY) WILL ESCALATE
- DIFFERENTIAL COST ESCALATION FACTOR (DCF)

$$DCF = \frac{(I_E + 1)^N}{(I_G + 1)^N}$$

I_E = ESCALATION RATE FOR DOMINANT INPUT VARIABLE (E.G., ENERGY)

I_G = GENERAL (AVERAGE) INFLATION RATE AFFECTING THE OTHER VARIABLES

N = YEAR

- ILLUSTRATION

N = 3

I_G = 4%

I_E = 12% (8% INCREMENTAL RATE)

$$DCE = \frac{(0.12 + 1)^3}{(0.04 + 1)^3} = 1.25$$

∴ THE ENERGY COSTS SHOULD BE MULTIPLIED BY 1.25 IN YEAR 3 <u>BEFORE</u> DISCOUNTING

SPECIAL ISSUES

- ECONOMIC LIFE VS. REQUIREMENTS VS. STUDY HORIZON
- RESIDUAL VALUE/SALVAGE
- DISCOUNT RATE
- IMPLICIT DISCOUNT RATE

CASH FLOW - PRESENT VALUE ANALYSIS

i = INTEREST RATE PER PERIOD

y = THE # OF INTEREST PERIODS

P = THE PRESENT WORTH OR VALUE TODAY

F = THE FUTURE WORTH OF MONEY OR VALUE AT y INTEREST PERIODS IN THE FUTURE

A = A UNIFORM END OF PERIOD SUM OF MONEY SUCH AS AN ANNUAL PAYMENT AT THE END OF THE YEAR

SINGLE COMPOUND AMOUNT (SCA): $F = P(1+i)^y$

SINGLE PAYMENT PRESENT WORTH (SPW): $P = \dfrac{F}{(1+i)^y}$

UNIFORM COMPOUND AMOUNT (UCA): $F = A\,\dfrac{(1+i)^y - 1}{i}$

UNIFORM SINKING FUND (USF): $A = \dfrac{F\,(i)}{\left[(1+i)^y - 1\right]}$

UNIFORM CAPITAL RECOVERY (UCR): $A = P\left[\dfrac{i(1+i)^y}{(1+i)^y - 1}\right]$

UNIFORM PRESENT WORTH (UPW): $P = A\left[\dfrac{(1+i)^y - 1}{i(1+i)^y}\right]$

SUB-SET #11

LCCA AND ECONOMIC PROJECTIONS

SELECTED TOPICS AND APPLICATIONS

- ECONOMIC ANALYSIS: PRESENT VALUE AND BREAK EVEN ANALYSIS

DISCOUNTING & PRESENT VALUE ANALYSIS

EXAMPLE:

ASSUME THAT OPPORTUNITY 'A' GENERATES BENEFITS EQUAL TO \$100, \$150, AND \$200 AT THE END OF YEARS 1, 2, AND 3, RESPECTIVELY. ASSUME THE OPPORTUNITY 'B' YIELDS BENEFITS OF \$225 IN YEAR 2, AND \$225 IN YEAR 3. THEREFORE, OVER THREE YEARS, OPPORTUNITY 'A' AND B YIELD BENEFITS OF \$450. HOWEVER, THE TIMING OF THE BENEFITS RECEIVED IS DIFFERENT IN EACH CASE. USING THE PRESENT VALUE TECHNIQUE, THEIR TWO BENEFIT FLOWS CAN BE VIEWED IN TERMS OF TODAY'S DOLLAR VALUE.

STEP #1: COMPUTE THE PRESENT VALUE FACTOR (PVF) USING THE PRESENT VALUE EQUATION:

$$PVF = \frac{1}{(1+I)^N}$$

WHERE: I = INTEREST RATE (DISCOUNT RATE)
N = YEAR IN WHICH THE BENEFIT IS RECEIVED

USING AN INTEREST RATE OF 10%, THE CALCULATION OF PRESENT VALUE FACTORS IS AS FOLLOWS:

$$\text{YEAR 1} = \frac{1}{(1+0.10)^1} = \frac{1}{(1.10)^1} = 0.9091$$

$$\text{YEAR 2} = \frac{1}{(1+0.10)^2} = \frac{1}{(1.10)^2} = 0.8264$$

$$\text{YEAR 3} = \frac{1}{(1+0.10)^3} = \frac{1}{(1.10)^3} = 0.7513$$

STEP #2: COMPUTE THE PRESENT VALUE OF EACH OPPORTUNITY BENEFIT FLOWS BY MULTIPLYING THE PRESENT VALUE FACTOR TIMES THE ANNUAL BENEFIT AMOUNT.

YEAR	PRESENT VALUE FACTOR	ANNUAL BENEFIT 'A'	ANNUAL BENEFIT 'B'	PRESENT VALUE 'A'	PRESENT VALUE 'B'
1	0.9091	$100	0	$ 90.91	0
2	0.8264	150	225	123.96	185.94
3	0.7513	200	225	150.26	169.04
TOTAL		$450	$450	$365.13	$354.98

CHOICE A IS PREFERRED: ITS PRESENT VALUE IS GREATER

SOURCE: LIFE CYCLE COSTING EMPHASIZING ENERGY CONSERVATION, REYNOLDS, SMITH & MILLS, JACKSONVILLE, FLORIDA, 1976.

IMPACT OF DISCOUNTING A DECISION ON RAM*

FISCAL YEAR	COST OF RAM* MOD	ANNUAL SAVINGS FROM MOD**	DISCOUNTED ANNUAL SAVINGS RATE +	DISCOUNTED ANNUAL SAVINGS ANNUAL MOD VALUE	SAVINGS REDUCTIONS FROM DISCOUNTING	INFLATED VALUE OF ANNUAL COST WITHOUT MOD RATE ++	INFLATED VALUE OF ANNUAL COST WITHOUT MOD COST & INF.
1965	$75M						
1966		$10M	.954	$9.54M	.46	1%	$10.1M
1967		$10M	.867	$8.67M	1.33	2%	$10.2M
1968		$10M	.788	$7.88M	2.12	4%	$10.4M
1969		$10M	.717	$7.17M	2.83	5%	$10.5M
1970		$10M	.652	$6.52M	3.48	8%	$10.8M
1971		$10M	.592	$5.92M	4.08	11%	$11.1M
1972		$10M	.538	$5.38M	4.62	13%	$11.3M
1973		$10M	.489	$4.89M	5.11	14%	$11.4M
1974		$10M	.445	$4.45M	5.55	24%	$12.4M
1975		$10M	.405	$4.05M	5.95	41%	$14.1M
TOTALS	$75M	$100M	.	$64.47M	$35.53M		$112.3M

REMARKS: THIS IS A HYPOTHETICAL EXAMPLE BUT USING ACTUAL DISCOUNT AND INFLATION RATES TO SHOW THE EFFECT EACH HAD ON A PROJECTED $10M ANNUAL SAVING IF A PARTICULAR RAM* MODIFICATION WAS INSTALLED. UNDISCOUNTED, THE $100M SAVINGS FROM THE $75M MOD IS GOOD BUSINESS. DISCOUNTED, THE SAVINGS ONLY TOTAL $64.47M; NOT A GOOD INVESTMENT, UNLESS INFLATION IS CONSIDERED, IN WHICH CASE THE MOD WOULD HAVE CAUSED A SLIGHT SAVINGS.

* RELIABILITY, AVAILABILITY, AND MAINTAINABILITY

** OR ANNUAL COST OF NOT HAVING MOD

\+ FROM DODI 7041.3, OCTOBER 18, 1972

++ FROM DOD DEFLATOR BASED ON ACTUAL INFLATION OF O&M COSTS, RATE OF INFLATION COMPARED WITH FY 65.

SOURCE: E. CRESSWELL, "NOTES ON DISCOUNTING", NOT PUBLISHED.

ILLUSTRATION OF PRICE DEFLATOR/INFLATOR INDICES

(FY 80 = 1.00)

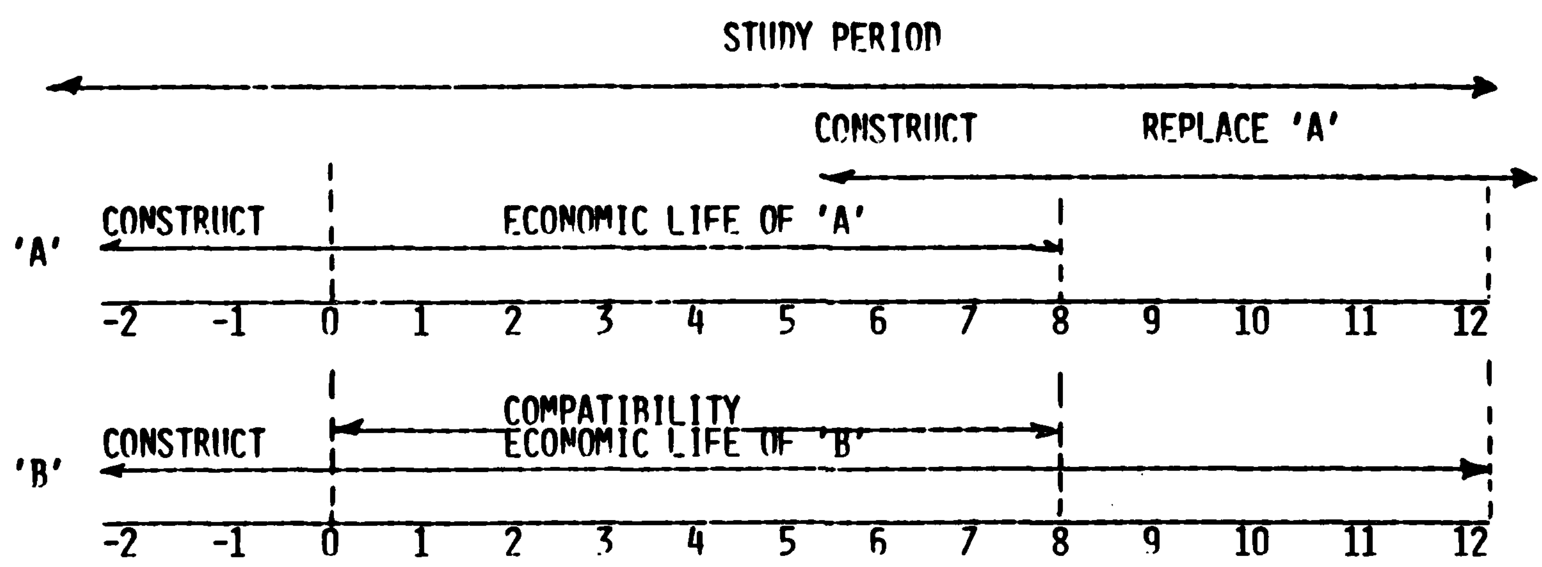
YEAR	GNP DEFLATOR	CONSTRUCTION	PROCUREMENT	PAY/WAGES
1950	0.30	0.25	0.34	0.23
1955	0.33	0.28	0.37	0.28
1960	0.37	0.33	0.43	0.37
1965	0.40	0.37	0.45	0.45
1970	0.51	0.49	0.50	0.50
1975	0.69	0.76	0.79	0.74
1980	1.00	1.00	1.00	1.00
(EST) 1985	1.48	1.42	1.45	1.44
(EST) 1990	2.10	1.85	1.94	2.06

ECONOMIC LIFE AND STUDY HORIZON - EXAMPLE

ASSUME THAT TWO PROJECTS ARE BEING EVALUATED AND THAT 'A' HAS AN ECONOMIC LIFE OF 8 YEARS AND 'B' HAS AN ECONOMIC LIFE OF 12 YEARS. FURTHER ASSUME THAT ALTERNATIVE 'A' COSTS $1,000 AND ALTERNATIVE 'B' COSTS $1,300 AND THAT EACH TAKES TWO YEARS TO CONSTRUCT WITH 50 PERCENT OF THE INVESTMENT COST DUE EACH YEAR. THIS PROBLEM IS DIAGRAMMED ON THE FOLLOWING PAGE.

SOURCE: LIFE CYCLE COSTING EMPHASIZING ENERGY CONSERVATION, REYNOLDS, SMITH & MILLS, JACKSONVILLE, FLORIDA, 1976.

EXAMPLE (CON'T)



THE DIAGRAM SHOWS THAT EACH PROJECT WILL TAKE 2 YEARS TO CONSTRUCT AND THAT IN YEAR 8 A SECOND 'A' WILL HAVE BEEN CONSTRUCTED TO REPLACE THE ORIGINAL 'A' WHICH WILL HAVE RUN ITS ECONOMIC IFE. THE STUDY PERIOD ENDS IN YEAR 12 WHICH IS THE END OF THE ECONOMIC LIFE OF 'B'. CONSEQUENTLY, IN YEAR 12, THE RESIDUAL VALUE OF 'A' MUST BE CREDITED AGAINST THE COST OF REPLACING 'A'.

EXAMPLE (CON'T)

THE NEXT STEP IN THE ANAYLSIS IS TO DISCOUNT THE INVESTMENT COST STREAMS USING PRESENT VALUE FACTORS.

YEAR	INVESTMENT COST 'A'	INVESTMENT COST 'B'	ANNUAL PRESENT VALUE FACTOR	PRESENT VALUE OF INVESTMENT 'A'	PRESENT VALUE OF INVESTMENT 'B'
-2	500	650	1.2100	605.00	786.50
-1	500	650	1.1000	550.00	715.00
7	500	--	0.5132	256.60	--
8	500	--	0.4665	233.25	--
12	(500)	--	0.3187	(159.35)	--
TOTAL	1500	1300		1485.50	1501.50 *

END OF YEAR VS. AVERAGE DISCOUNT FACTORS (10%)

YEARS	END OF YEAR FACTOR	AVERAGE FACTOR
0	1.000	
1	0.909	0.954
2	0.826	0.867
3	0.751	0.788
4	0.683	0.717
5	0.621	0.652

EXAMPLE

A PARTICULAR PROJECT BEING EVALUATED BY THE NAVY HAS THE FOLLOWING COSTS:

	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5
INVESTMENT					
ADPE		\$2,000			
SYSTEM DEVELOPMENT	\$300	\$ 200			
SITE PREPARATION	\$100				
ANNUAL OPERATING		\$ 300	\$600	\$700	\$700

OVER THE YEARS ADPE COSTS FOR THIS TYPE OF HARDWARE HAVE BEEN ESCALATING AT A RATE WHICH IS 3% BELOW THE NORMAL RATE. THIS TREND IS EXPECTED TO CONTINUE IN THE FUTURE. EVALUATE THE PROJECT IN TERMS OF ITS PRESENT VALUE.

SOURCE: NAVAL DATA AUTOMATION COMMAND, ECONOMIC ANALYSIS PROCEDURES FOR ADP, PUB. 15-7000, MARCH 1980.

PV WITHOUT INFLATION

YEAR	COSTS	DISCOUNT FACTOR	DISCOUNTED COSTS	CUMULATIVE DISCOUNTED COSTS
1	$400.0	.954	$381.6	$381.6
2	2500.0	.867	2167.5	2549.1
3	600.0	.788	472.8	3021.9
4	700.0	.717	501.9	3523.8
5	700.0	.652	456.4	3980.2

THE PV = $3980.2

THE NEXT STEP IS TO PERFORM THE ANALYSIS IN TERMS OF CURRENT DOLLARS THAT INCORPORATE THE DIFFERENTIAL INFLATION RATE FOR ADPE OF -3%.

PV WITH -3% INFLATION FOR ADPE

YEAR	COSTS	DISCOUNT FACTOR	DISCOUNTED COSTS	CUMULATIVE DISCOUNTED COSTS
1	$400.0	.954	$381.6	$381.6
2	500.0	.867	433.5	815.1
2	2000.0*	.833*	1666.0*	2481.1
3	600.0	.788	472.8	2953.9
4	700.0	.717	501.9	3455.8
5	700.0	.652	456.4	3912.2

PV = $3912.2

*A -3% INFLATION RATE IS APPLIED TO THE ADPE COST.

SOURCE: NAVAL DATA AUTOMATION COMMAND, ECONOMIC ANALYSIS PROCEDURES FOR ADPE, PUB 15-7000, MARCH 1980.

<u>RECOMMENDED PRACTICE FOR DOD COST ANALYSES</u>

1. CONSTANT DOLLAR TIME PHASED PROJECTION
   - SPECIFIC BASE YEAR (E.G. CURRENT FY YR + 1)
2. DISCOUNTED PROJECTION
   - TYPICALLY 10% PER ANNUM
3. CURRENT DOLLAR TIME-PHASED PROJECTION
   - DIFFERENTIAL ESCALATION FACTORS

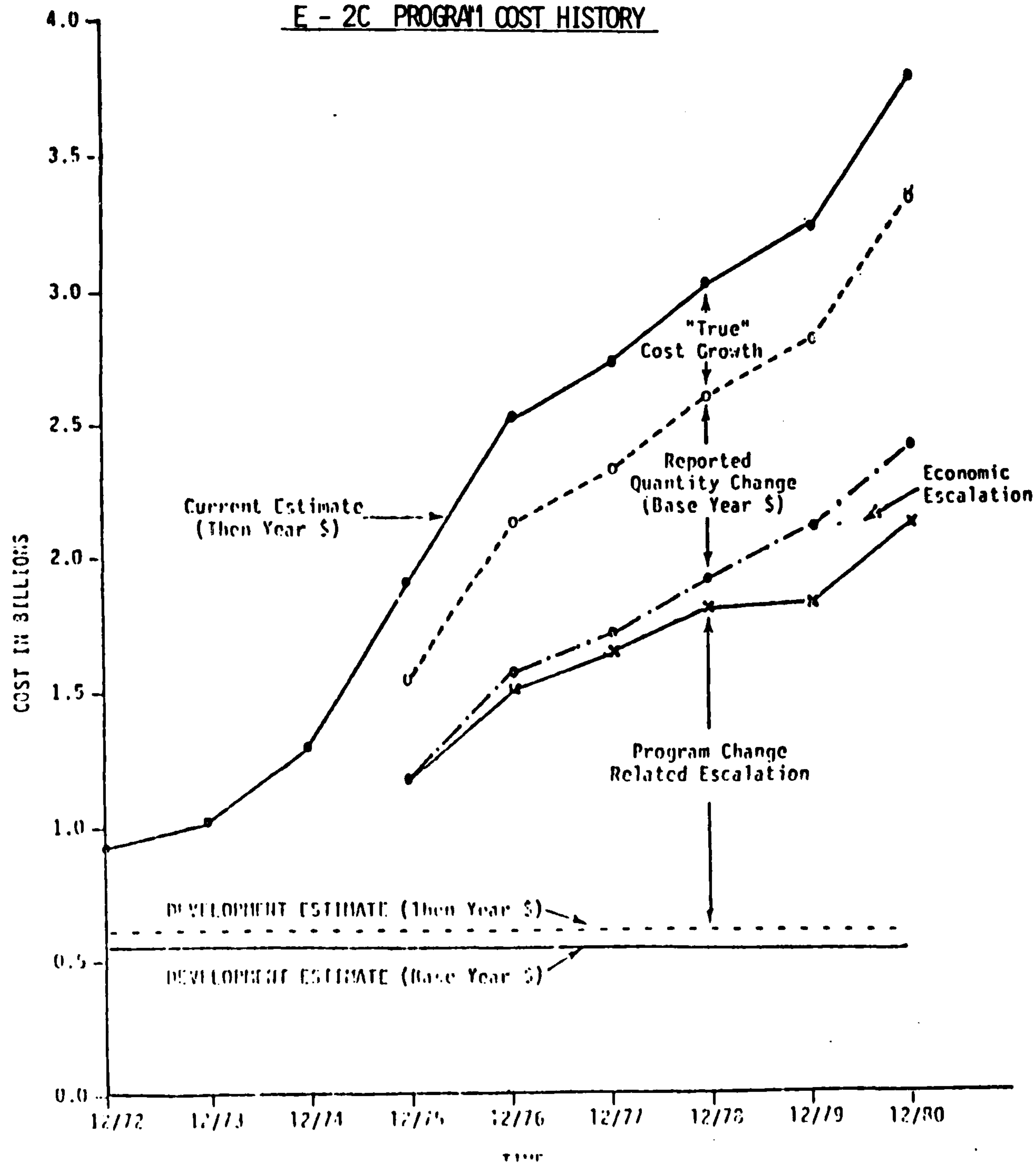
(SEE: DOD I 7041.3)

COST MAGNITUDE

- THREE VIEWS ON "COST GROWTH"
- CURRENT "THEN-YEAR" DOLLARS: IMPORTANT IN MEASURING <u>BUDGET</u> EFFECTS (INFLATION IMPACT)
- CONSTANT "BASE-YEAR" DOLLARS: IMPORTANT IN MEASURING <u>PROGRAM MANAGEMENT</u> EFFECTS
- QUANTITY ADJUSTMENT: IMPORTANT IN ACCURATELY COMPARING DEVELOPMENT ESTIMATE (DE) TO CURRENT ESTIMATE (CE)

SOURCE: G. McNICHOLS, DoD COST SYMPOSIUM, OCTOBER 1981.

E-2C PROGRAM COST HISTORY



Source McNichols Oct 81.

THE E-2C PROGRAM COST HISTORY IS PRESENTED AS AN EXAMPLE OF THE TYPES OF COST GROWTH. THE COSTS SHOWN REFLECT THE DECEMBER SAR OF EACH YEAR. THE CURRENT ESTIMATE (THEN YEAR $) LINE SHOWS THAT THE TOTAL PROGRAM COSTS CONTINUE TO INCREASE. THIS IS THE COST GROWTH THE CONGRESS TENDS TO POINT TO AS A BUDGET EFFECT. THE "TRUE" COST GROWTH REGION REPRESENTS BASE-YEAR DOLLAR GROWTH DUE TO ALL PROGRAM CHANGES EXCEPT QUANTITY. "TRUE" COST GROWTH HAS REMAINED ESSENTIALLY CONSTANT FOR THE LAST 4 YEARS. A LARGE PORTION OF THE PROGRAM GROWTH IS DUE TO REPORTED QUANTITY CHANGES (BASE YEAR $). HERE THE TOTAL QUANTITY PROCURED HAS INCREASED. THE FIGURE ILLUSTRATES THE NEED TO MAKE THE QUANTITY ADJUSTMENT WHEN CALCULATING COST GROWTH. THE NEXT REGION IS COST GROWTH DUE TO CHANGES IN ESCALATION RATES, WHICH IS CALLED ECONOMIC ESCALATION IN THE SARS. THE LARGEST CATEGORY FOR PROGRAM COST GROWTH IS PROGRAM CHANGE RELATED ESCALATION. THIS CATEGORY INCLUDES THE ESCALATION (OR INFLATION) ASSOCIATED WITH <u>ALL</u> PROGRAM CHANGES, (QUANTITY, SCHEUDLE, ESTIMATING, ENGINEERING, OR OTHERS). AFTER REMOVING THE VARIOUS COST CHANGES FROM THE CURRENT ESTIMATE (THEN YEAR $), THE DEVELOPMENT ESTIMATE (THEN YEAR $) REMAINS. THE DIFFERENCE BETWEEN THE DE IN THEN YEAR $ AND THE DE IN BASE YEAR $ WAS THE PRE-PLANNED INFLATION INCLUDED IN THE DE.

COST GROWTH FIGURES FOR THE THREE VIEWS ARE:

- CURRENT "THEN YEAR" DOLLARS - 542.5%
- CONSTANT "BASE YEAR" DOLLARS - 242.7%
- QUANTITY ADJUSTMENT "TRUE" COST GROWTH - 36.3%

SOURCE; MCNICHOLS, OCT 81

SAR PROGRAM COST SUMMARY
AS OF 31 DECEMBER 1980
55 SYSTEMS – DOLLAR COMPARISON ($ BILLIONS)

SERVICE	MEASURE	DEVELOPMENT ESTIMATE	DEVELOPMENT ESTIMATE ADJUSTED FOR QUANTITY	OTHER PROGRAM CHANGES	ECONOMIC ESCALATION	CURRENT ESTIMATE	PER CENT GROWTH ADJUSTED FOR QUANTITY
ARMY (17)	CURRENT	32.5	36.6	28.3	12.6	77.5	111.7%
	BASE YEAR	21.8	21.9	7.7	----	29.6	35.2%
			14.7			47.9	225.8%
AIR FORCE (15)	CURRENT	32.8	41.4	17.1	12.0	70.5	70.2%
	BASE YEAR	24.3	28.2	6.7	----	34.9	23.9%
			13.2			35.6	169.1%
NAVY (23)	CURRENT	72.9	107.5	38.8	23.6	170.0	58.0%
	BASE YEAR	55.3	68.3	15.6	----	83.9	22.9%
			39.3			86.1	119.1%

THE SAR PROGRAM COST SUMMARY PRESENTS THE COST GROWTH FIGURES BASED ON THE TOTAL COSTS FOR 55 SAR SYSTEMS. THE 55 SYSTEMS INCLUDE THE NON-CONGRESSIONAL SARS AND COUNT CERTAIN AIR FORCE AND NAVY PROGRAMS AS SEPARATE ENTITIES, (E.G., AIM-9M, AIM-7M).

THE <u>% GROWTH: UNADJUSTED</u> FIGURE OF 129.9% REPRESENTS THE COST GROWTH BASED ON CURRENT THEN YEAR DOLLARS. IT INCLUDES ALL PROGRAM CHANGES AND ESCALATION. IT CORRESPONDS TO THE FIRST VIEW OF COST GROWTH.

THE <u>% GROWTH: ADJUSTED FOR QUANTITY</u> FIGURE OF 71.3% REPRESENTS COST GROWTH BASED ON CURRENT THEN YEAR DOLLARS BUT INCREASING THE DE. BASELINE TO THE CURRENT QUANTITY. THE QUANTITY INCREASE COSTING $47.3B IN THEN YEAR DOLLARS IS ADDED TO ARRIVE AT THE $185.6B ADJUSTED BASELINE.

THE <u>% GROWTH: ADJUSTED FOR QUANTITY AND ESCALATION</u> OF 25.4% REPRESENTS COST GROWTH BASED ON BASE YEAR DOLLARS. IT CORRESPONDS TO THE THIRD VIEW OF COST GROWTH, WHAT WE CALLED "TRUE" COST GROWTH.

THE <u>% GROWTH OF INFLATION</u> FIGURE OF 152.4% INDICATES THAT INFLATION IS THE MAJOR CONTRIBUTOR TO COST GROWTH. THE INCREASE FROM $67.2B PLANNED ESCALATION, TO $169.6B CURRENTLY ESTIMATED FOR TOTAL ESCALATION, IS A LARGER PERCENTAGE INCREASE THAN ANY FIGURE SHOWN. THE INFLATION TOTAL IS LARGER THAN THE BASE YEAR TOTAL, (I.E., MORE THAN HALF THE COST OF THE CURRENT ESTIMATE, FOR THESE 55 WEAPON SYSTEMS).

SOURCE: McNICHOLS, OCT'81.

SUBSYSTEM TRADEOFFS: AVIONICS SPARES INVESTMENT COST VERSUS FAULT DIAGNOSIS ACCURACY, RELIABILITY, AND MODULARITY

PROBLEM: MANY EXISTING AVIONICS EQUIPMENTS HAVE COMBINED CANNOT DUPLICATE (CND) AND RETEST OK (RETOK) LEVELS IN EXCESS OF 40 PERCENT

OBJECTIVES:

- TO ANALYZE POTENTIAL TRADEOFFS BETWEEN SUPPORT COSTS AND DIFFERENT MODULAR CONFIGURATIONS AS A FUNCTION OF FAULT DIAGNOSIS ACCURACY AND RELIABILITY
- TO REDUCE FAULT ISOLATION DIFFICULTIES AND COSTS THROUGH DESIGN IMPROVEMENTS

THE PROBLEM: LOW RELIABILITY IN AVIONICS . . .

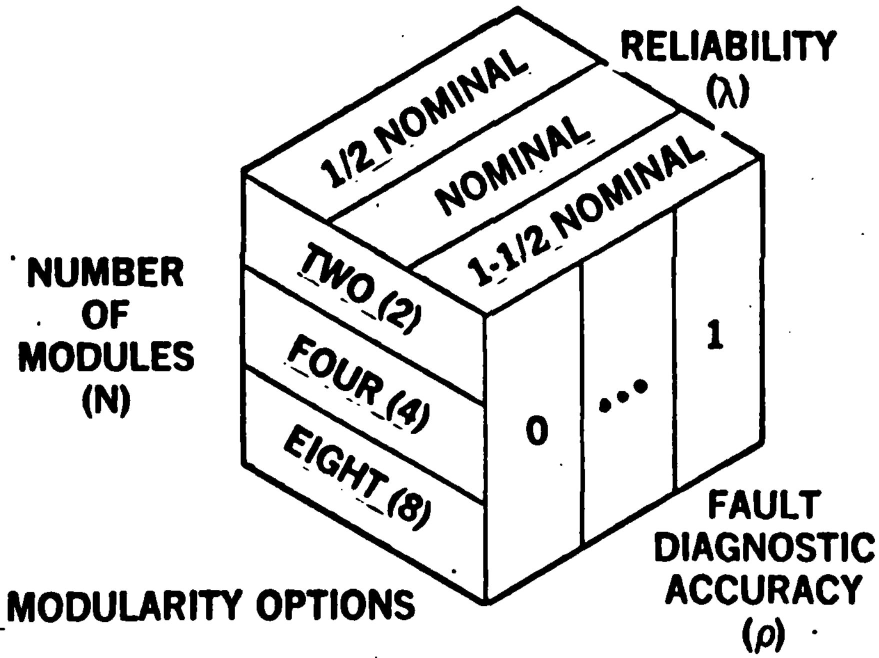
SUBSYSTEM	MTBF SPEC/DEMO	MTBF FIELD EXPERIENCE
• DOPPLER RADAR (A-7D)	250	48
• HEADS-UP DISPLAY (A-7D)	350	88
• FORWARD LOOKING RADAR (RF-4C)	90	15
• SEARCH RADAR	150	39
• NAVIGATION -ALTITUDE RADAR	1000	59

COUPLED WITH POOR FAULT DIAGNOSIS:

TYPICAL $RETOK_{B\&D}$ 30% TO 50%

HYPOTHETIC AVIONICS EQUIPMENT EXAMPLE

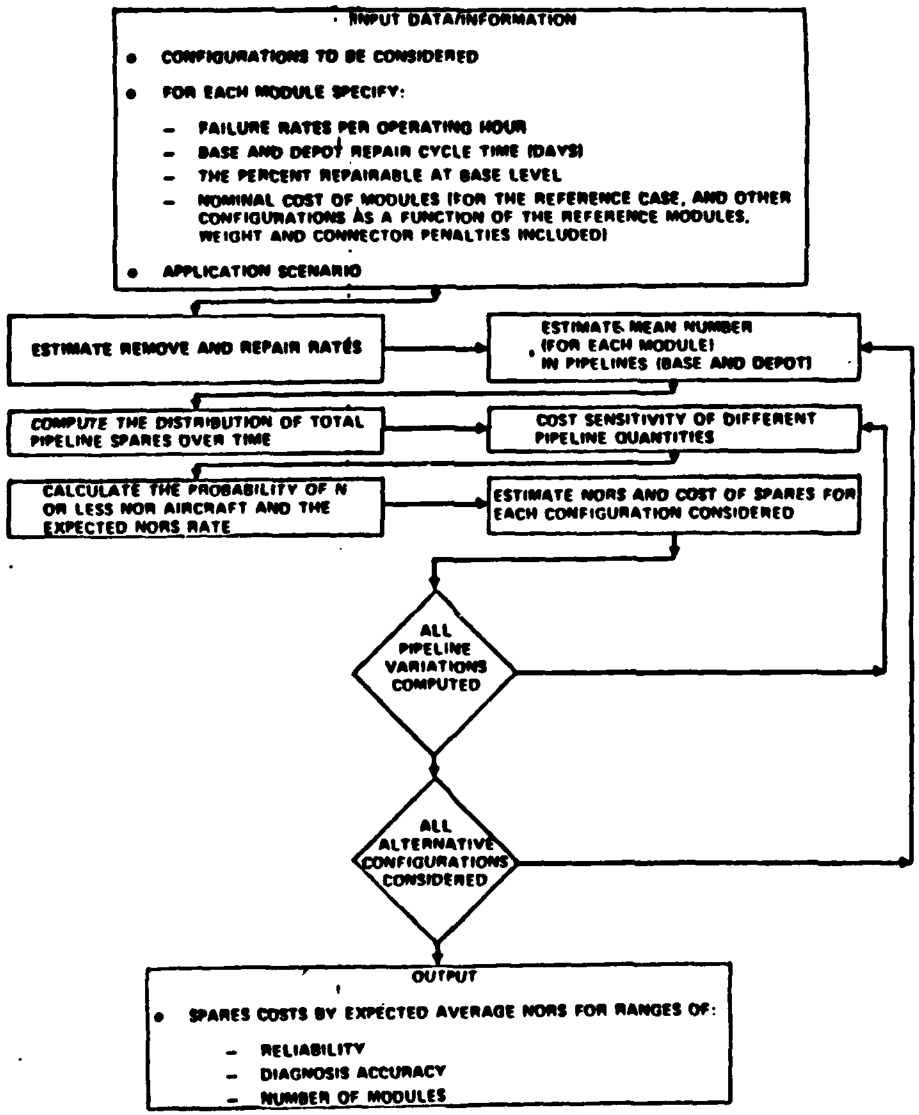
- UNDER WHAT DIAGNOSTIC ACCURACY AND RELIABILITY CONDITIONS WILL ONE DESIGN BE PREFERRED OVER OTHERS WITH RESPECT TO SPARES INVESTMENT COSTS?



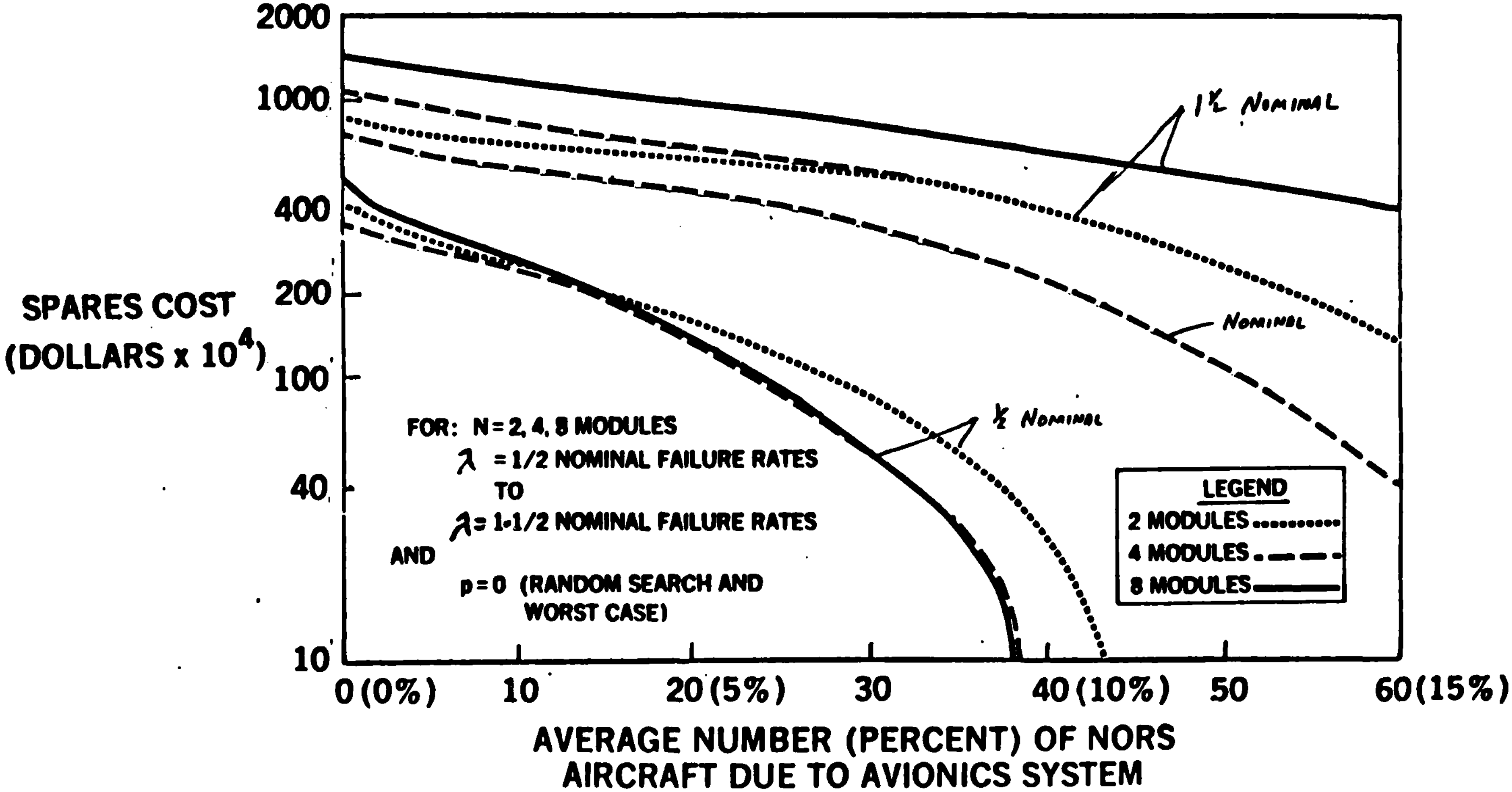
- COSTS OF MODULARITY OPTIONS

C_2 = \$ 80,000
C_4 = \$120,000
C_8 = \$160,000

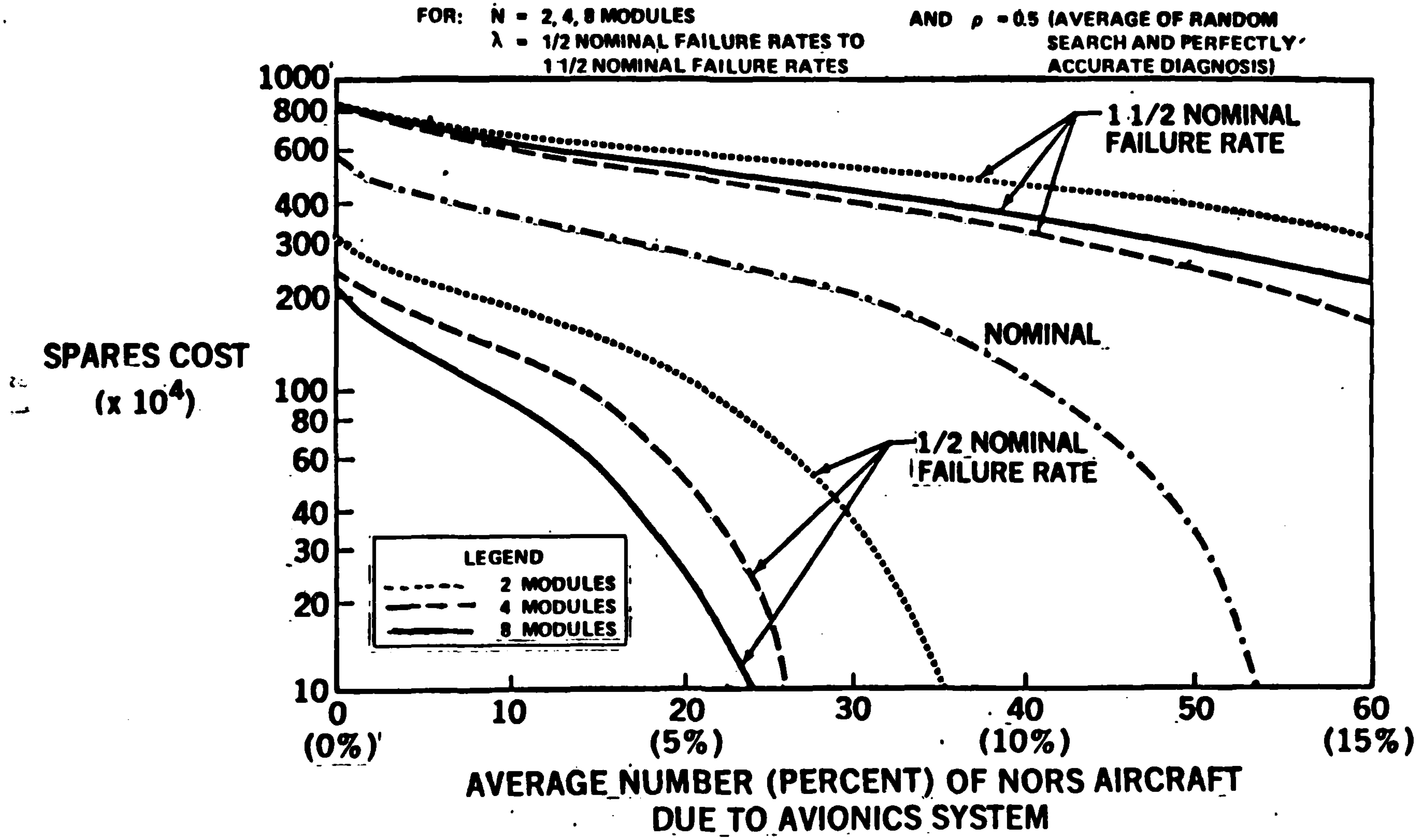
METHODOLOGY TO COMPUTE AVERAGE NORS VERSUS SPARES AS A FUNCTION OF NUMBER OF MODULES RELIABILITY AND FAULT DIAGNOSIS ACCURACY



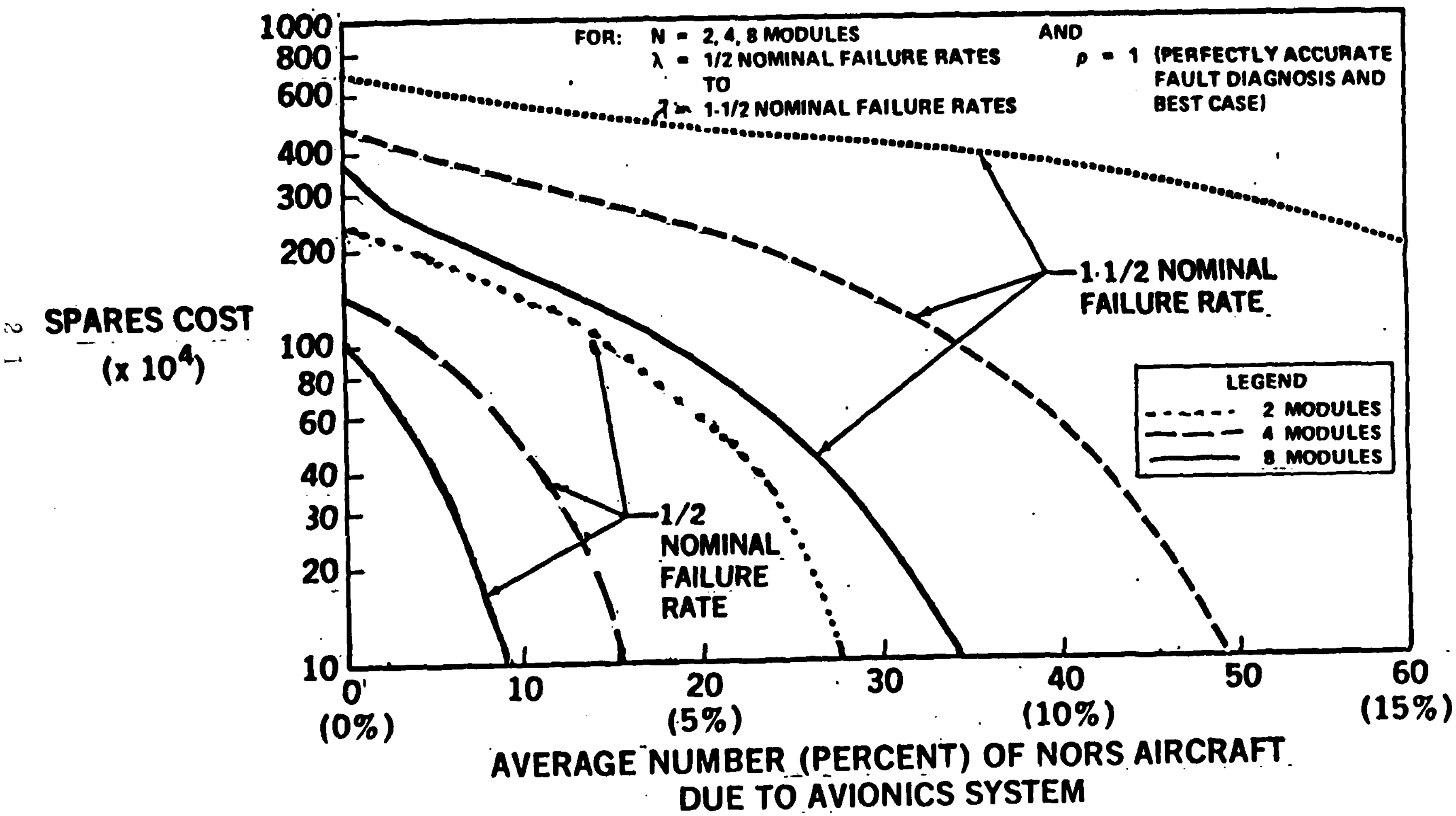
SPARES VERSUS AVERAGE NORS: RANDOM DIAGNOSIS



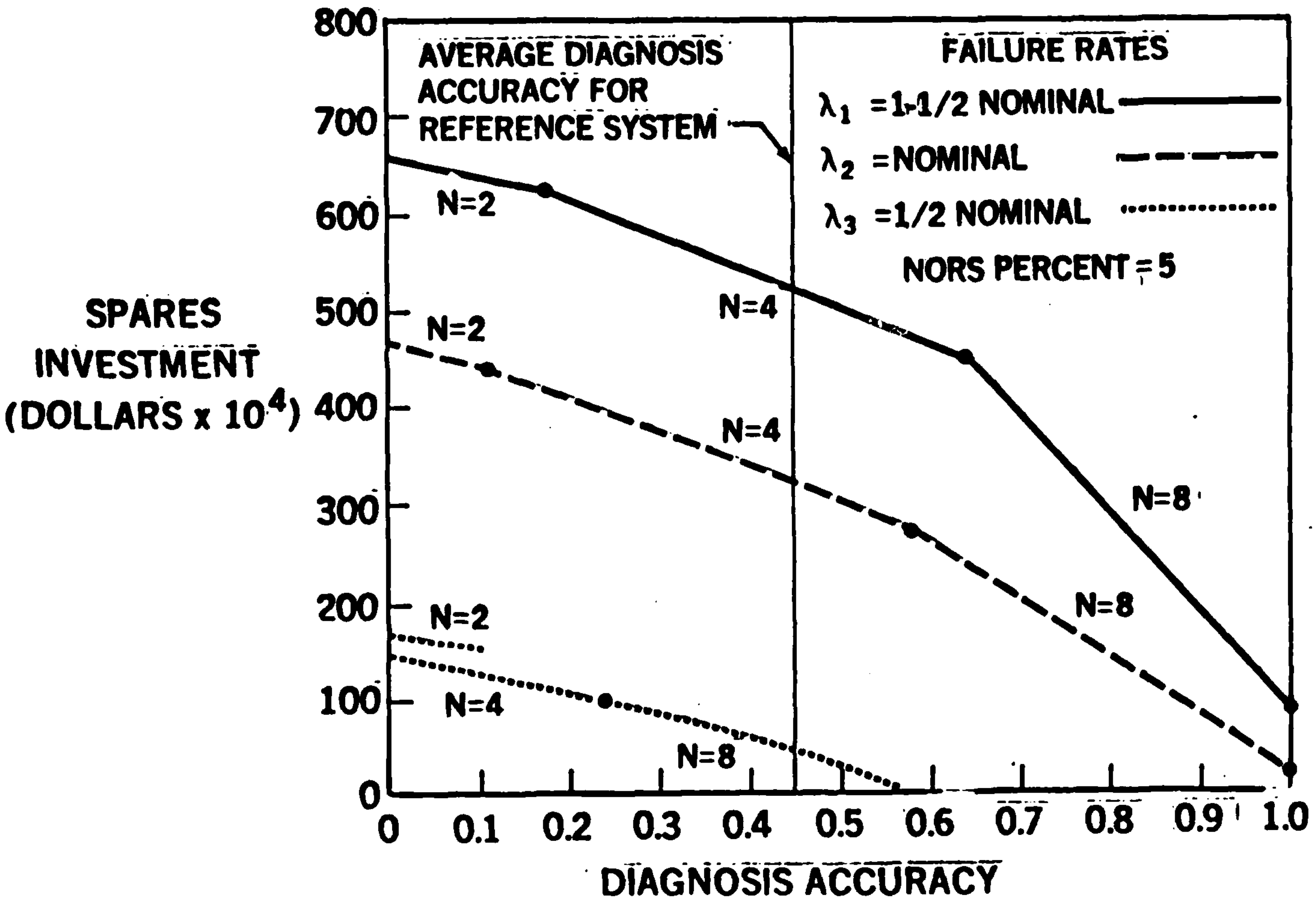
SPARES COST VERSUS AVERAGE NORS: EQUAL MIX OF PERFECT AND RANDOM DIAGNOSIS



SPARES COST VERSUS AVERAGE NORS: PERFECT DIAGNOSIS



SPARES INVESTMENT VERSUS DIAGNOSIS ACCURACY



EXAMPLE: RADAR SYSTEM DESIGN

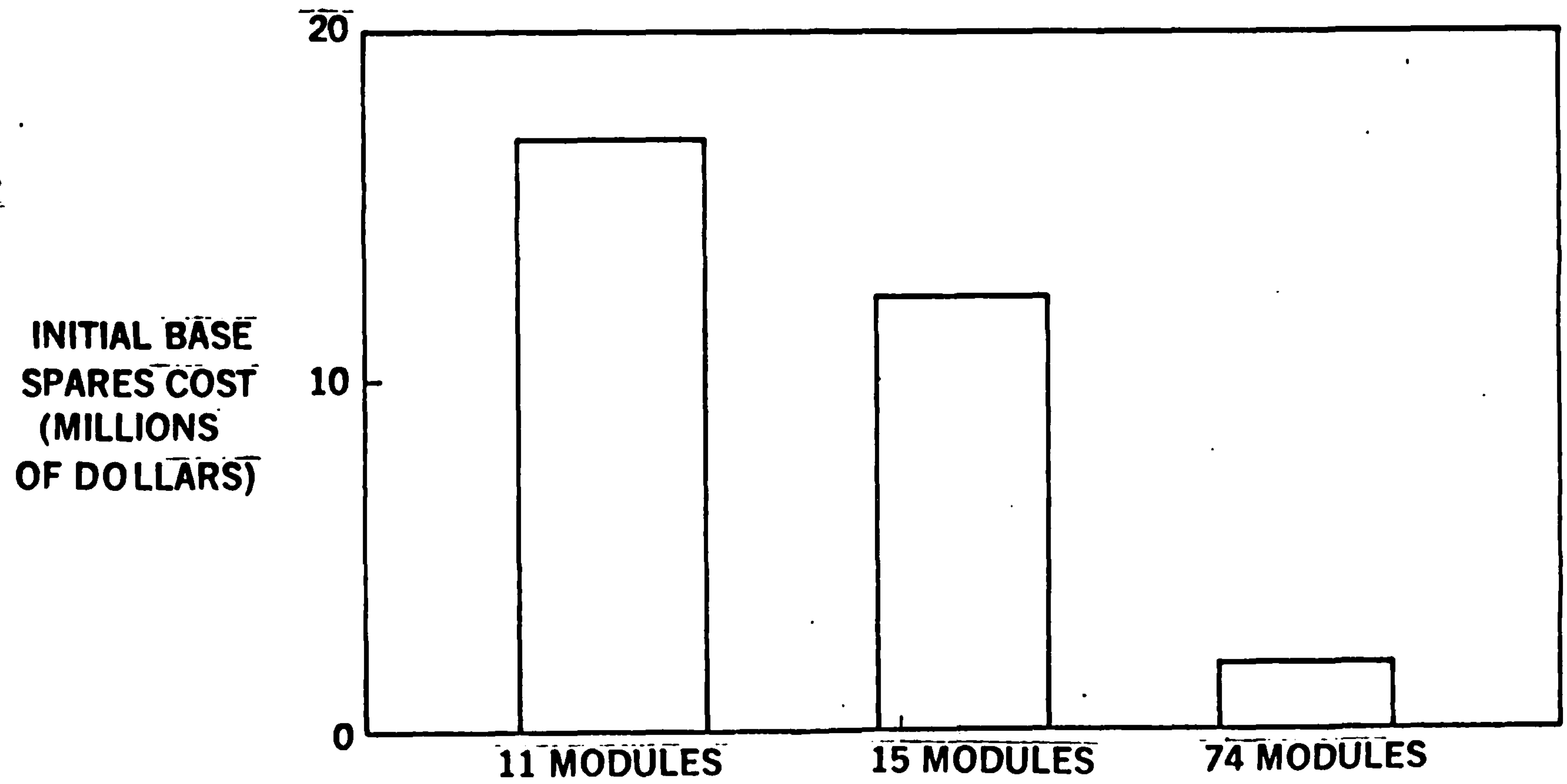
DESIGN OPTIONS (SAME RELIABILITY/PERFORMANCE)

- 74 MODULES
- 11 MODULES
- 15 MODULES

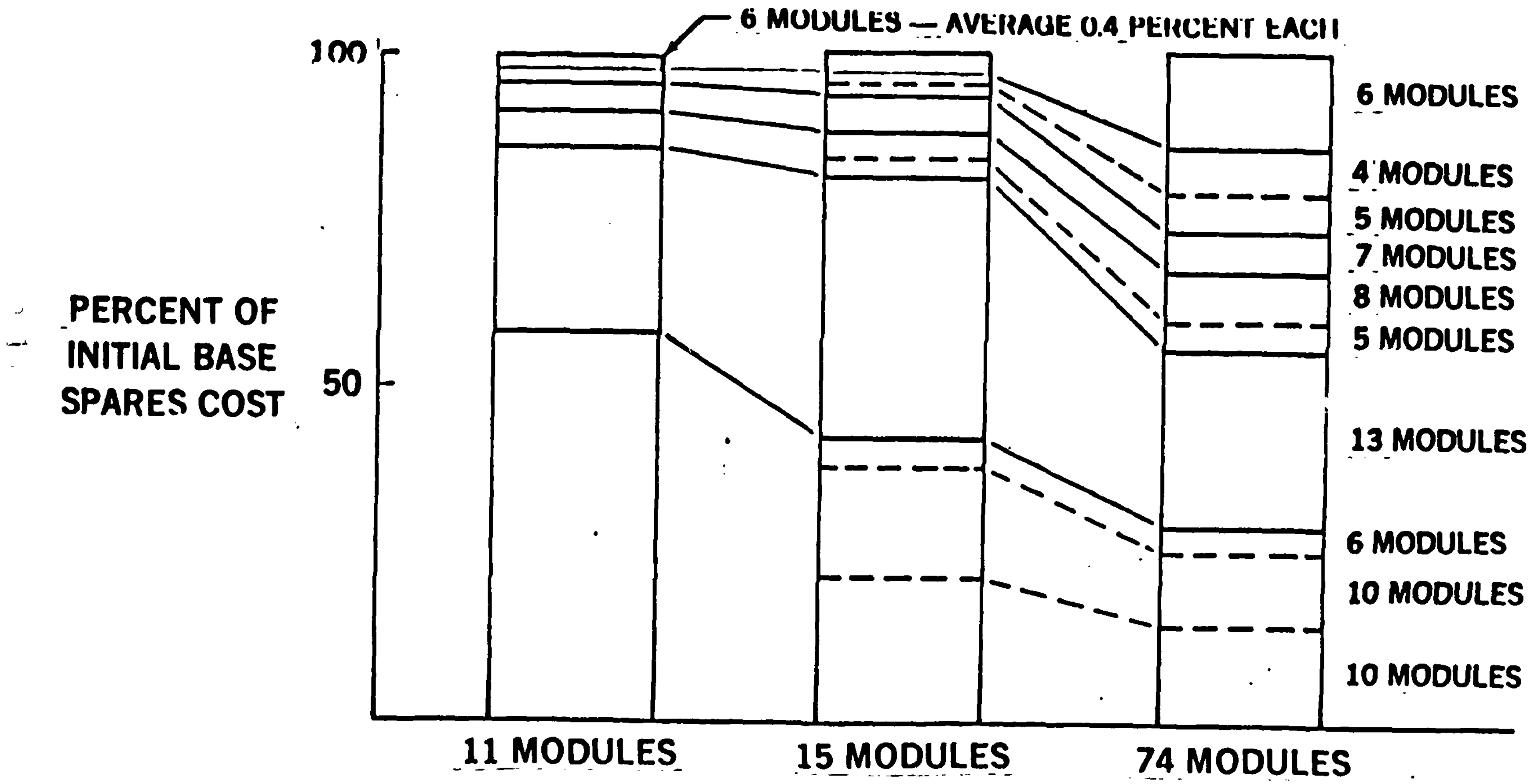
CONSTANT SUPPLY SYSTEM AVAILABILITY

WHAT IS THE SENSITIVITY OF SPARES COSTS TO DEGREE OF MODULARITY

INITIAL BASE SPARES SENSITIVITY TO MODULARITY SUPPLY SYSTEM AVAILABILITY — 0.99



RESOURCE DISTRIBUTION OF DIFFERENT MODULARITY



SUMMARY - MODULARITY

ADVANTAGES	DISADVANTAGES
GREATER DESIGN FLEXIBILITY	HIGHER AQUISITION COSTS
SELECTIVE RELIABILITY IMPROVEMENT PROGRAMS	COMPLICATED AND EXPENSIVE SOFTWARE REQUIRED FOR FAILURE ISOLATION
ISOLATION OF HIGH RISK COMPONENTS	INCREASED PROBABILITY OF CONNECTION RELATED FAILURES
POTENTIAL REDUCTION OF REMOVE AND REPLACE TIME	IF DIAGNOSTIC ACCURACY IS POOR PERSONNEL AND MATERIAL MAINTENANCE COSTS CAN INCREASE
LOWER SPARES INVESTMENT	

CRITERIA FOR EVALUATING WEAPON SYSTEM AVAILABLITY, RELIABILITY AND COST

IMPROVED SYSTEM MISSION COST-EFFECTIVENESS THROUGH SUBSYSTEM RELIABILITY, AVAILABILITY AND COST TRADEOFFS BY:

1. ESTABLISHING RELIABILITY REQUIREMENTS OR GOALS WHICH CAN BE STATED AS DESIGN OBJECTIVES.
2. EVALUATING RELIABILITY REQUIREMENTS OR GOALS DURING THE DESIGN PROCESS, TEST AND EVALUATING PROCESS, AND OPERATIONAL PHASE OF THE SYSTEM.
3. EVALUATING THE IMPACT ON LIFE CYCLE COST FOR MAJOR MODIFICATIONS OR ENGINEERING CHANGES.
4. ASSESSING THE PROBABILITY OF MISSION SUCCESS OR THE READINESS POSTURE OF THE SYSTEM.
5. IDENTIFYING SUBSYSTEMS OR MAJOR COMPONENTS WHICH WILL PROVIDE THE GREATEST COST-EFFECTIVE BENEFITS THROUGH RELIABILITY IMPROVEMENT.
6. ESTIMATING THE COST OF SYSTEM DOWNTIME RESULTING FROM LOW RELIABILITY.

DEFINITIONS

A_S = <u>SYSTEM AVAILABILITY:</u> THE PROBABILITY THAT ONE SYSTEM WILL BE OPERATIONALLY READY TO INITIATE ITS MISSION AT ANY RANDOM POINT IN TIME

R_S = <u>SYSTEM RELIABILITY:</u> THE PROBABILITY THAT A SINGLE SYSTEM WHICH IS INITIALLY AVAILABLE WILL PERFORM ITS INTENDED MISSION WITHOUT A CRITICAL FAILURE

E_S = <u>SYSTEM EFFECTIVENESS OR PROBABILITY OF MISSION SUCCESS:</u> THE PROBABILITY THAT A SYSTEM WILL BE BOTH AVAILABLE TO INITIATE A MISSION AT A RANDOM POINT IN TIME AND WILL BE CAPABLE OF COMPLETING THE MISSION WITHOUT A CRITICAL FAILURE

MDT = <u>MEAN DOWNTIME:</u> THE SUM OF THE MEAN CORRECTIVE MAINTENANCE TIME PLUS LOGISTICS DELAY TIME

DEFINITIONS (CONT)

C_D = <u>COST OF SYSTEM UNAVAILABILITY:</u> THE COST OF EXTRA SYSTEMS REQUIRED TO ASSURE WITH PROBABILITY P THAT SUFFICIENT SYSTEMS WILL BE AVAILABLE TO COMPLETE THE MISSION AT A RANDOM POINT IN TIME. IT IS A MEASURE OF REDUNDANCY AT THE SYSTEM LEVEL

C_A = <u>COST OF ACHIEVING RELIABILITY GROWTH:</u> THE COSTS OF DESIGN, DEVELOPMENT, ACQUISITION AND MANAGEMENT TO ACHIEVE INCREASED RELIABILITY

C_M = <u>COST OF MAINTENANCE.</u> THE COSTS OF INTERMEDIATE AND DEPOT MAINTENANCE (LABOR AND MATERIAL)

ρ = <u>FAILURE CRITICALITY:</u> THE PROBABILITY THAT A FAILURE WILL CAUSE A MISSION ABORT IF IT OCCURS AT A RANDOM POINT IN TIME

Υ = <u>SYSTEM DUTY CYCLE:</u> THE RATIO OF ACTUAL OPERATING TIME TO THE TOTAL TIME THE SYSTEM IS IN A OPERABLE CONDITION

ILLUSTRATION OF COST VERSUS MTBF RESULTING IN DIFFERENT PROBABILITIES OF MISSION SUCCESS

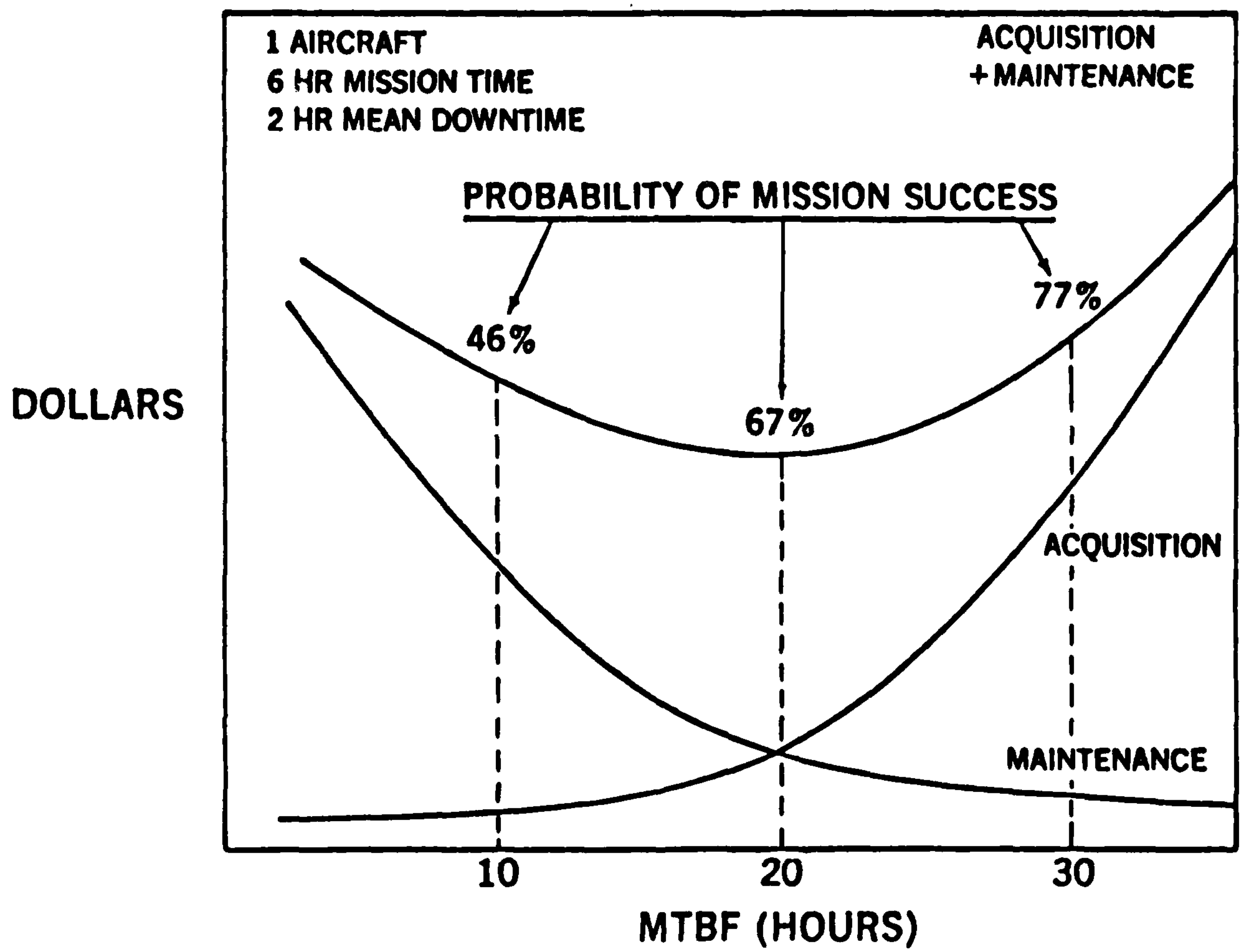
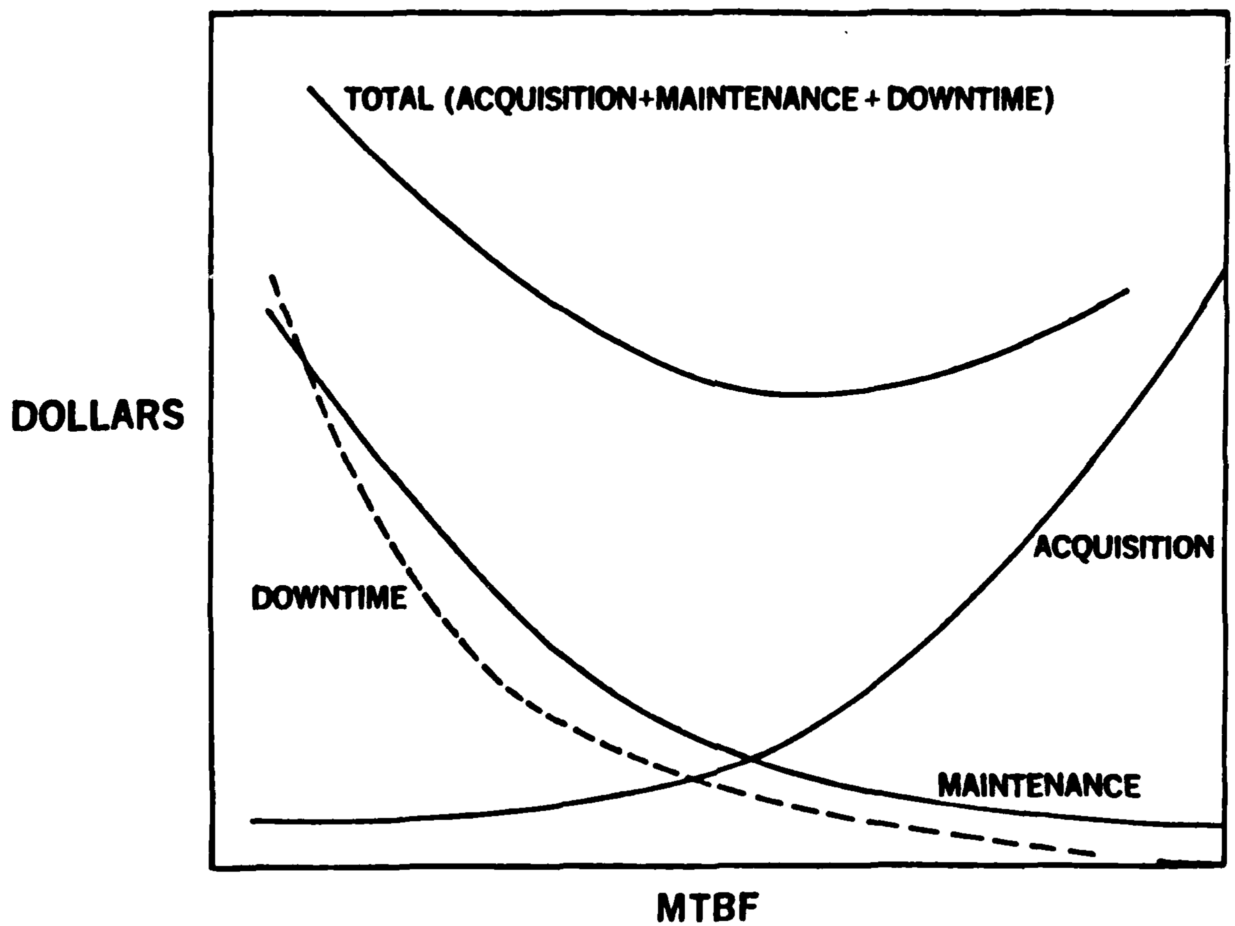


ILLUSTRATION OF COST VERSUS MTBF WITH EQUAL PROBABILITY OF MISSION SUCCESS



CONCEPT OF DOWNTIME COST

	LOW RELIABILITY		HIGH RELIABILITY
PROBABILITY OF SUCCESS	0.9	EQUAL	0.9
MISSION REQUIREMENT	10 AIRCRAFT	EQUAL	10 AIRCRAFT
RELIABILITY	12 AIRCRAFT		11 AIRCRAFT
AVAILABILITY	20 AIRCRAFT		16 AIRCRAFT
ACQUISITION COST	HIGHER		LOWER
OPERATIONAL COST	HIGHER		LOWER

EQUATIONS USED IN DERIVATION OF DOWNTIME COST

$$R = e^{-T/MTBF}$$

$$A = \frac{MTBF}{MTBF + MDT} \; ; \; \frac{MTBF + (1 - \rho) r\, MDT}{MTBF + r\, MDT}$$

$$E = R \bullet A$$

$$P = \sum_{i=0}^{N-M} \binom{N}{i} E^{N-i} (1 - E)^{i}$$

$$C_d = \Big[\underbrace{U(N - M)}_{\text{ACQUISITION}} + \underbrace{LS(N - M)}_{\text{OWNERSHIP}} \Big] G$$

DEFINITIONS

R = RELIABILITY

T = MISSION TIME

MTBF = MEAN TIME BETWEEN FAILURE

A = AVAILABILITY

MDT = MEAN DOWN TIME

E = SYSTEM EFFECTIVENESS

C_D = COST OF SYSTEM UNAVAILABILITY

U = SYSTEM UNIT COST

N = NO. OF SYSTEMS TO PURCHASE

M = NO. OF SYSTEMS REQUIRED

L = NO. OF FLYING HOURS OVER SYSTEM LIFE

S = SUPPORT COST PER FLYING HOUR

G = NO. OF GROUPS OF SYSTEMS

r = duty cycle time

PERCENT OF REPORTED FAILURES CAUSING ABORTS

AIRCRAFT	SYSTEM (%)	RANGE OF SUBSYSTEMS (%)
FIGHTERS		
F-4B	2.01	6.1-0.3
F-4C	1.65	5.0-0.0
F-5A	1.10	19.5-0.0
F-104C	1.25	7.7-0.0
F-105D	0.93	13.8-0.0
F-111A	1.67	8.8-0.0
BOMBERS		
B-52D	0.08	2.0-0.0
B-52G	0.06	0.5-0.0
B-52H	0.10	1.0-0.0
B-58A	0.33	1.8-0.0

PERCENT OF REPORTED FAILURES CAUSING ABORTS (CONT)

AIRCRAFT	SYSTEM (%)	RANGE OF SUBSYSTEMS (%)
TRANSPORT TYPES		
C-123B	1.23	6.0-0.0
C-130E	0.59	1.7-0.0
EC-135C	0.08	0.35-0.0
C-141A	0.36	1.08-0.0
C-7A	0.93	4.00-0.0
OTHER		
T-38A	2.84	8.4-0.0
E-2A	0.48	10.67-0.0
A-6A	2.00	12.07-0.17
P-3B	1.16	4.0-0.0

ALLOWING FOR:

- CRITICAL FAILURES FACTOR (ρ_S)
- DUTY CYCLE TIMES (r_S)

$$A_S = \frac{1 + (1 - \rho_S)\, r_S \,\lambda\, MDT}{1 + r_S \,\lambda\, MDT}$$

WHERE:

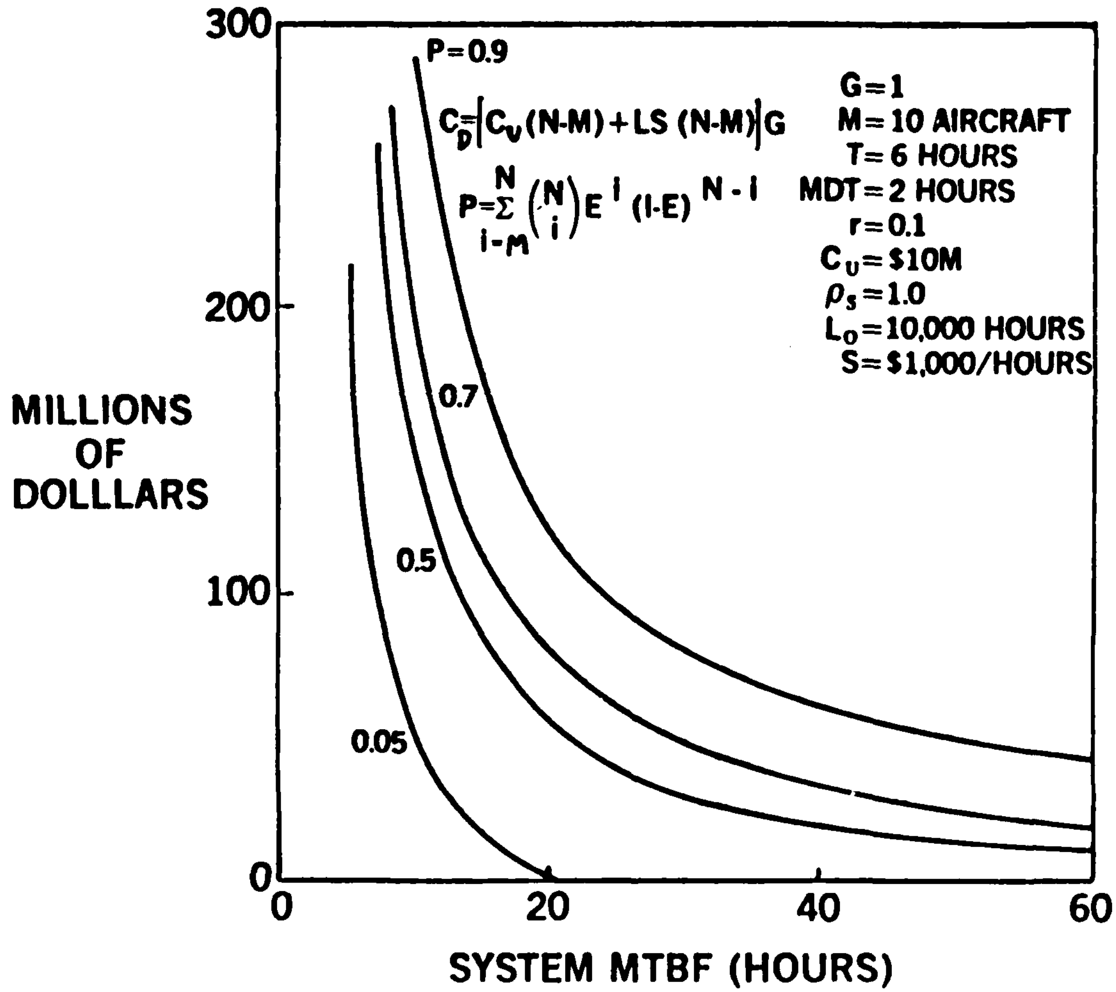
$$\rho_S = \frac{\sum_{i=1}^{m} \rho_i \cdot \lambda_i}{\sum_{i=1}^{m} \lambda_i}$$

$$\lambda_i = \frac{1}{MTBF_i}$$

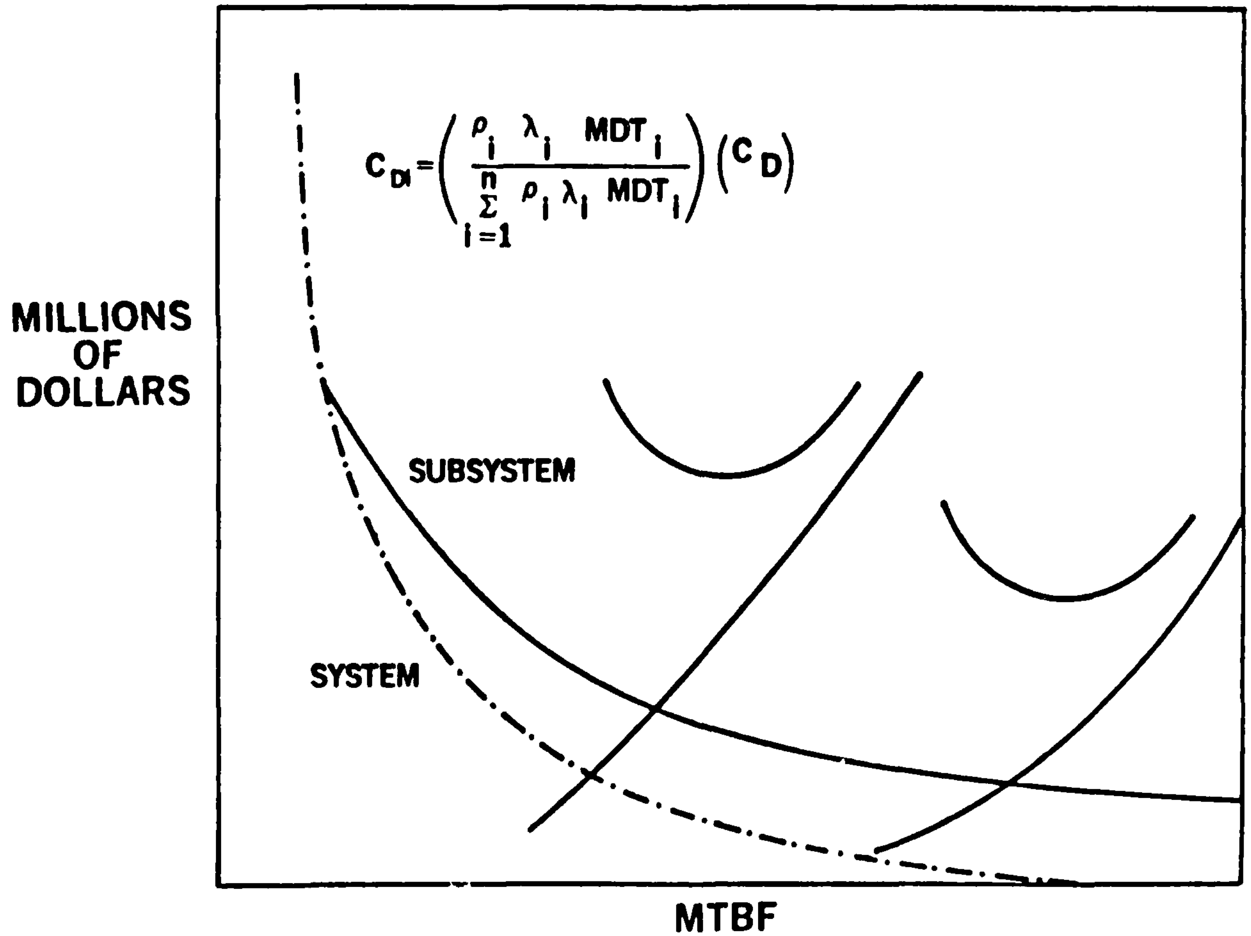
$$r_S = \frac{\sum_{i=1}^{m} TOT_i}{\sum_{i=1}^{m} (TOT_i + TNRT_i)}$$

$$R_S = e^{-\rho_s \lambda t}$$

ILLUSTRATION OF COST OF SYSTEM DOWNTIME



DISTRIBUTION OF C_D TO SUBSYSTEMS



PRINCIPAL METHODS OF ACHIEVING RELIABILITY

INITIAL DESIGN ANALYSIS (REDUNDANCY)

PROTOTYPE TESTING FOR RELIABILITY

DESIGN IMPROVEMENTS

PARTS IMPROVEMENTS

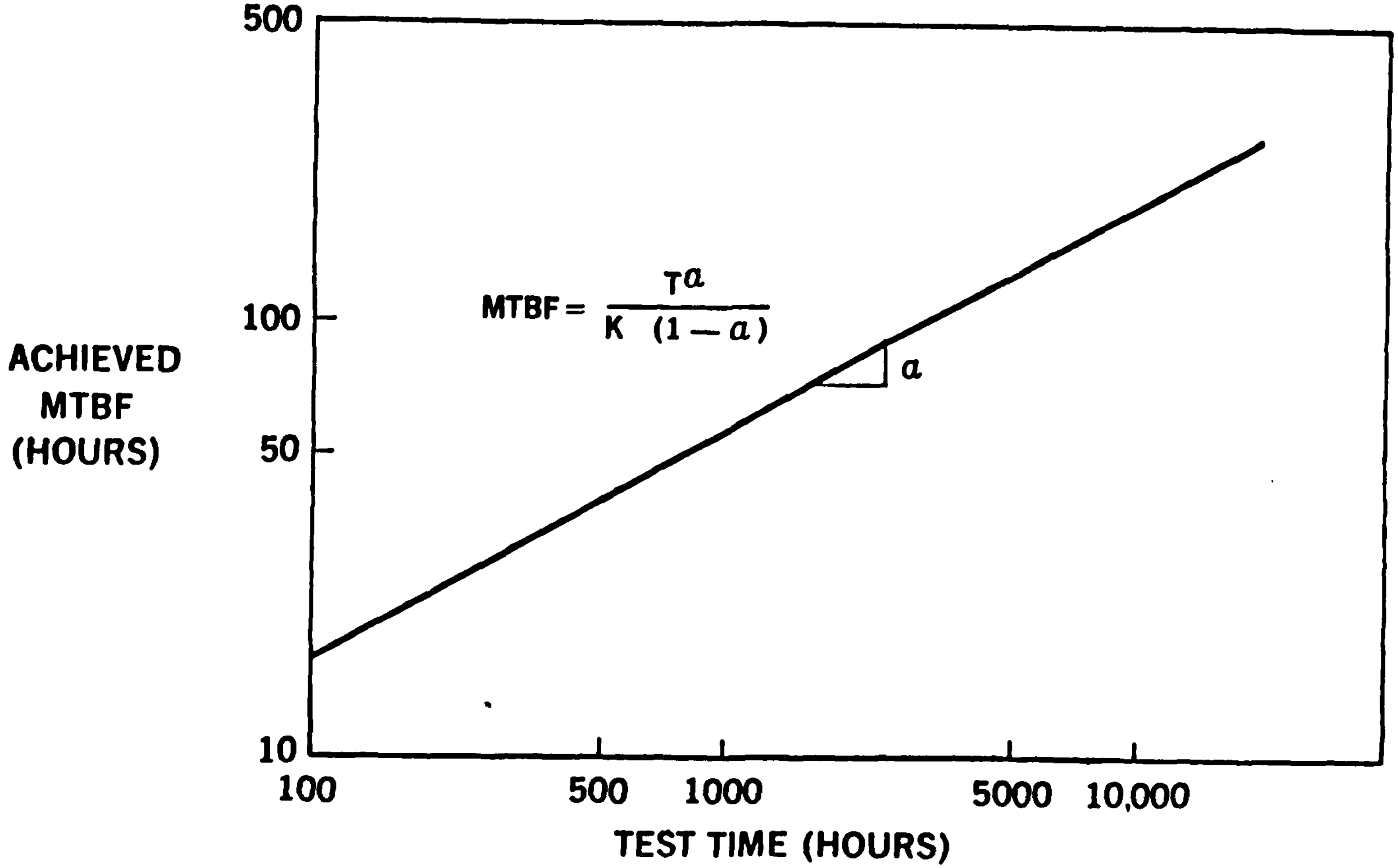
- JAN PARTS
- JAN (TX) PARTS
- HI REL PARTS
- DERATED PARTS

QUALITY CONTROL IMPROVEMENTS

PRODUCTION METHODS IMPROVEMENTS

TRAINING IMPROVEMENTS

THE DUANE MODEL OF RELIABILITY GROWTH



COST OF ACHIEVING RELIABILITY MODEL

$$C_R = C_E + C_P + C_I$$

COST = INITIAL DESIGN AND DEVELOPMENT COST FOR MTBF + INITIAL PRODUCTION COST FOR MTBF + RELIABILITY IMPROVEMENT COST

- TESTING
- PROTOTYPE PRODUCTION
- DESIGN IMPROVEMENT
- PARTS IMPROVEMENT
- QUALITY CONTROL IMPROVEMENT

RELIABILITY IMPROVEMENT COST MODEL

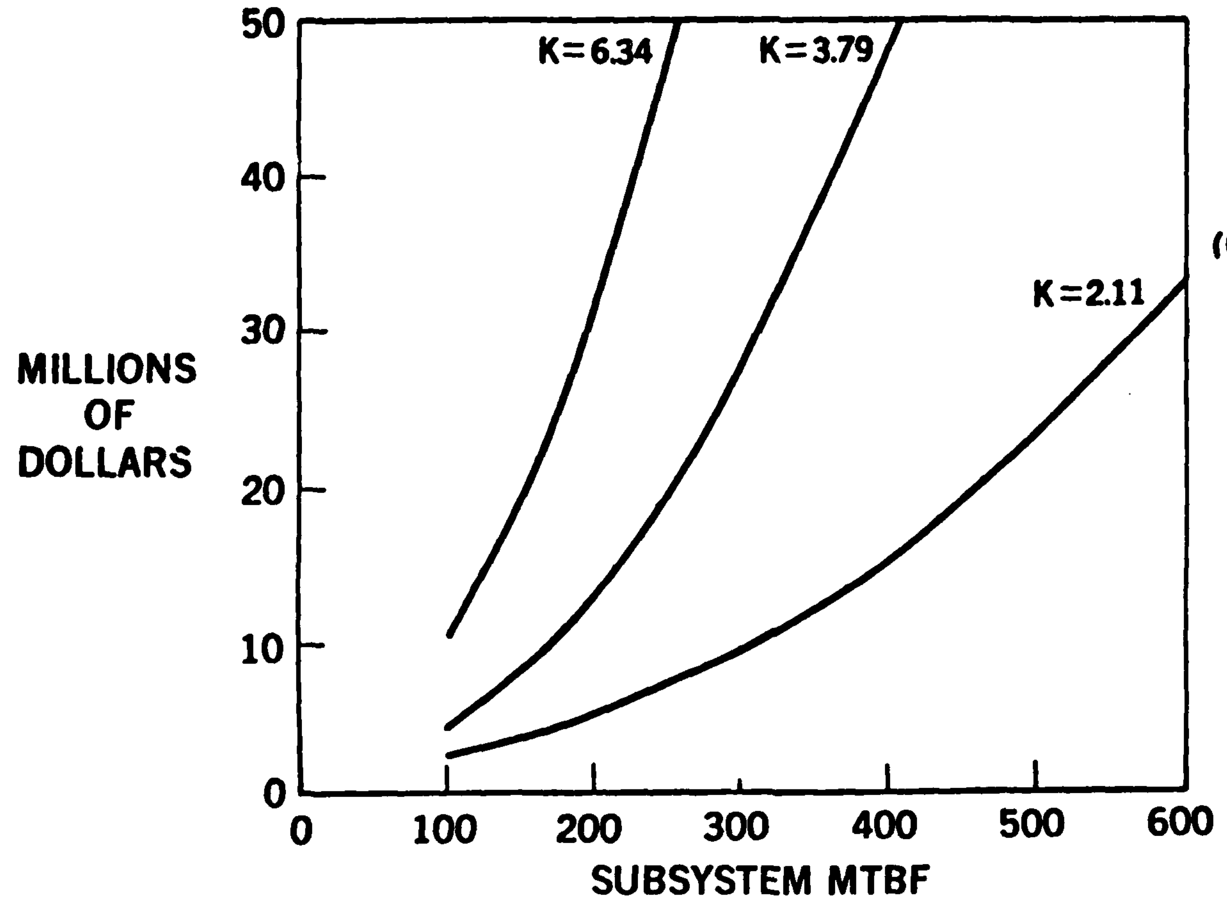
(BASED ON DUANE RELIABILITY GROWTH APPROXIMATION)

$$\text{COST} = \begin{pmatrix}\text{BASIC}\\ \text{DESIGN}\\ \text{COST}\end{pmatrix} + \begin{pmatrix}\text{COST OF}\\ \text{TEST}\\ \text{ASSY'S}\end{pmatrix} + \begin{pmatrix}\text{TESTING}\\ \text{COSTS}\end{pmatrix} + \left[\begin{pmatrix}\text{DESIGN \\$}\\ \text{PER}\\ \text{FAILURE}\end{pmatrix} + \begin{pmatrix}\text{PARTS \\$}\\ \text{PER}\\ \text{FAILURE}\end{pmatrix} + \begin{matrix}\text{Q.C. \\$}\\ \text{PER}\\ \text{FAILURE}\end{pmatrix}\begin{pmatrix}\text{NO. OF}\\ \text{SYSTEMS}\end{pmatrix}\right]\begin{pmatrix}\text{NO. OF}\\ \text{TEST}\\ \text{FAILURES}\end{pmatrix}$$

$$= C_{DES} + N_\rho C_\rho + TC_1 + \left[\rho_2 C_2 + \left(\rho_3 C_3 + \rho_4 C_4\right) N \cdot G\right]\left(F\right)$$

$$= C_{DES} + N_\rho C_\rho + \left[\text{MTBF}\,(1-\alpha)\,K\right]^{1/\alpha} (C_1) + \left[\rho_2 C_2 + (\rho_3 C_3 + \rho_4 C_4)\, N \cdot G\right]\left[\text{MTBF}\,(1-\alpha)\,K\right]^{1/\alpha - 1}$$

ILLUSTRATION OF COST OF ACHIEVING RELIABILITY



$a = 0.5$

$C_l = \$75/\text{HOUR}$

$C_{DES} + N_P C_P = \$125{,}000$

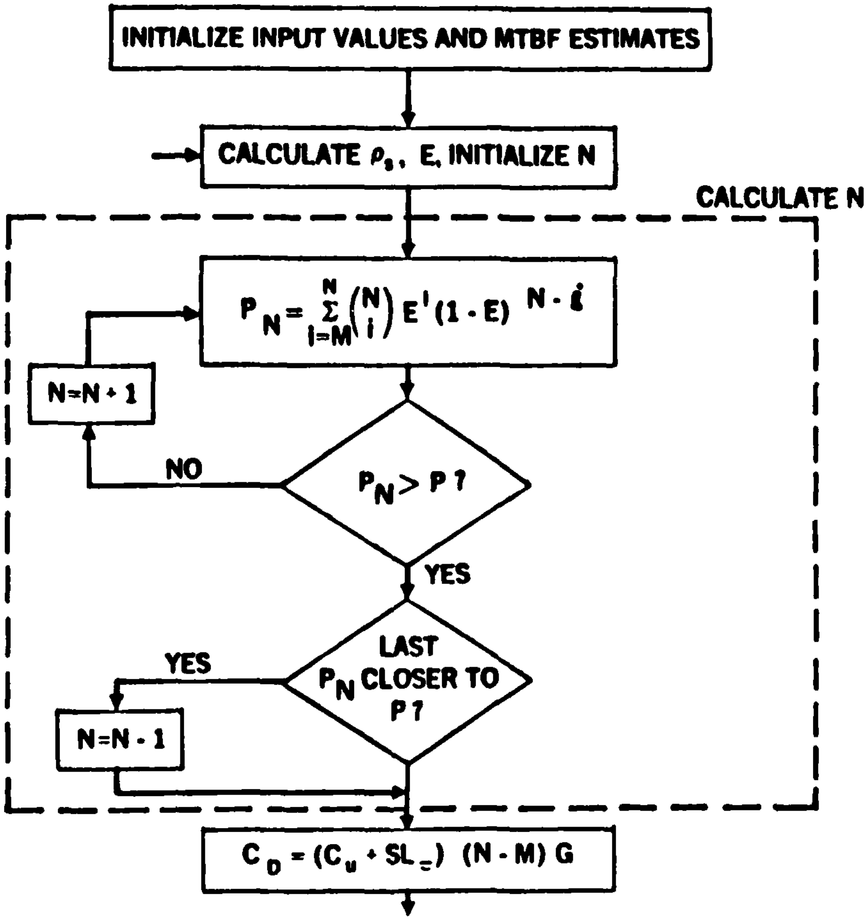
$(C_2P_2 + NG(C_3P_3C_4P_4)) = \$56$

MAINTENANCE & SUPPORT COST MODEL

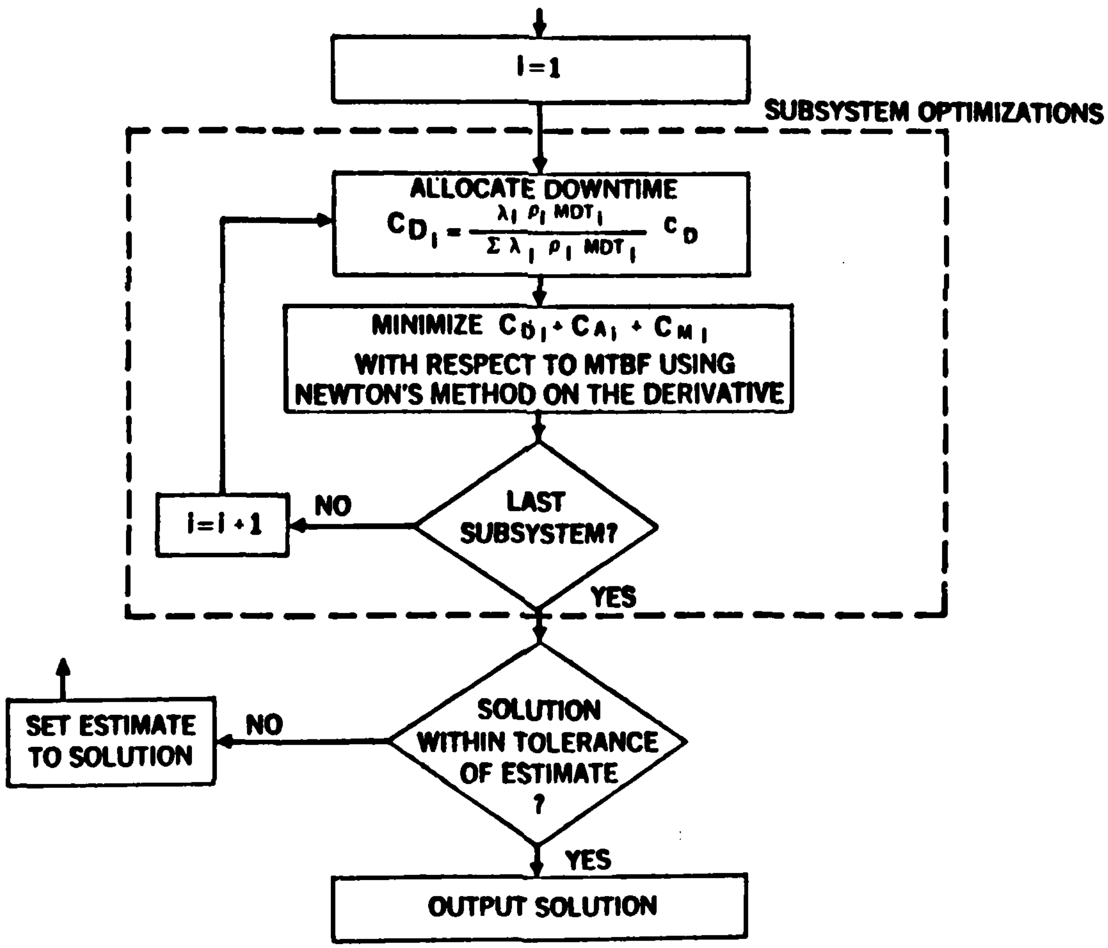
$$\text{COST} = \sum_{G} \left(\begin{array}{c} \text{Average} \\ \text{Cost Per} \\ \text{Failure} \end{array} \right) \times \left(\begin{array}{c} \text{Failure} \\ \text{Rate} \\ \text{Per} \\ \text{Operating} \\ \text{Hour} \end{array} \right) \times \left(\begin{array}{c} \text{Life} \\ \text{Cycle} \\ \text{Operating} \\ \text{Hours Per} \\ \text{Unit} \end{array} \right) \times \left(\begin{array}{c} \text{Number} \\ \text{Of} \\ \text{Units} \end{array} \right)$$

$$= (S) \times (\lambda) \times (L) \times (N)$$

FLOWCHART OF RELIABILITY/COST MODEL SOLUTION PROCEDURE

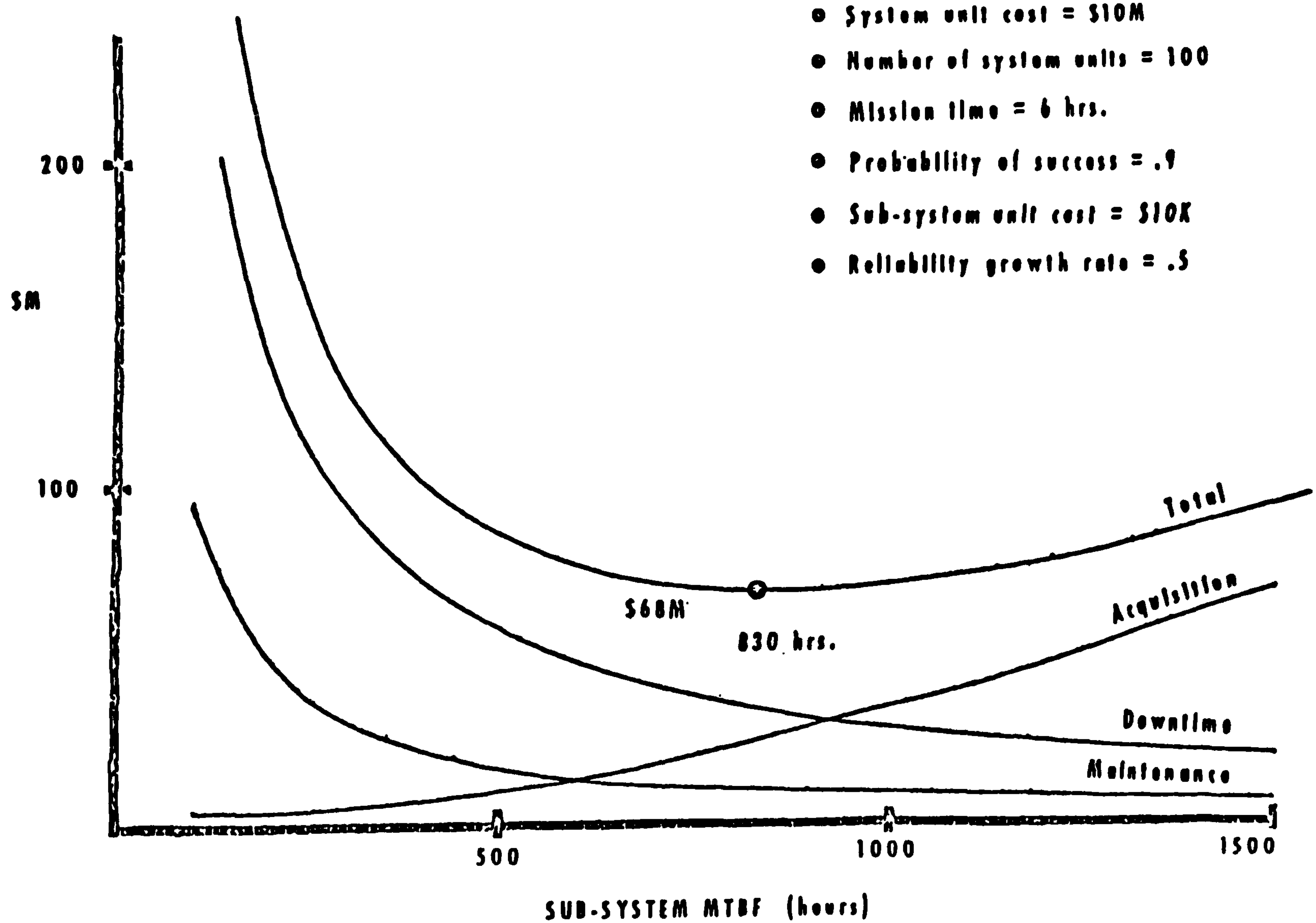


FLOWCHART OF RELIABILITY/COST MODEL SOLUTION PROCEDURE (CONTINUED)



COST vs. RELIABILITY
System Downtime Included

- System unit cost = $10M
- Number of system units = 100
- Mission time = 6 hrs.
- Probability of success = .9
- Sub-system unit cost = $10K
- Reliability growth rate = .5



COST VERSUS RELIABILITY
SYSTEM DOWNTIME EXCLUDED

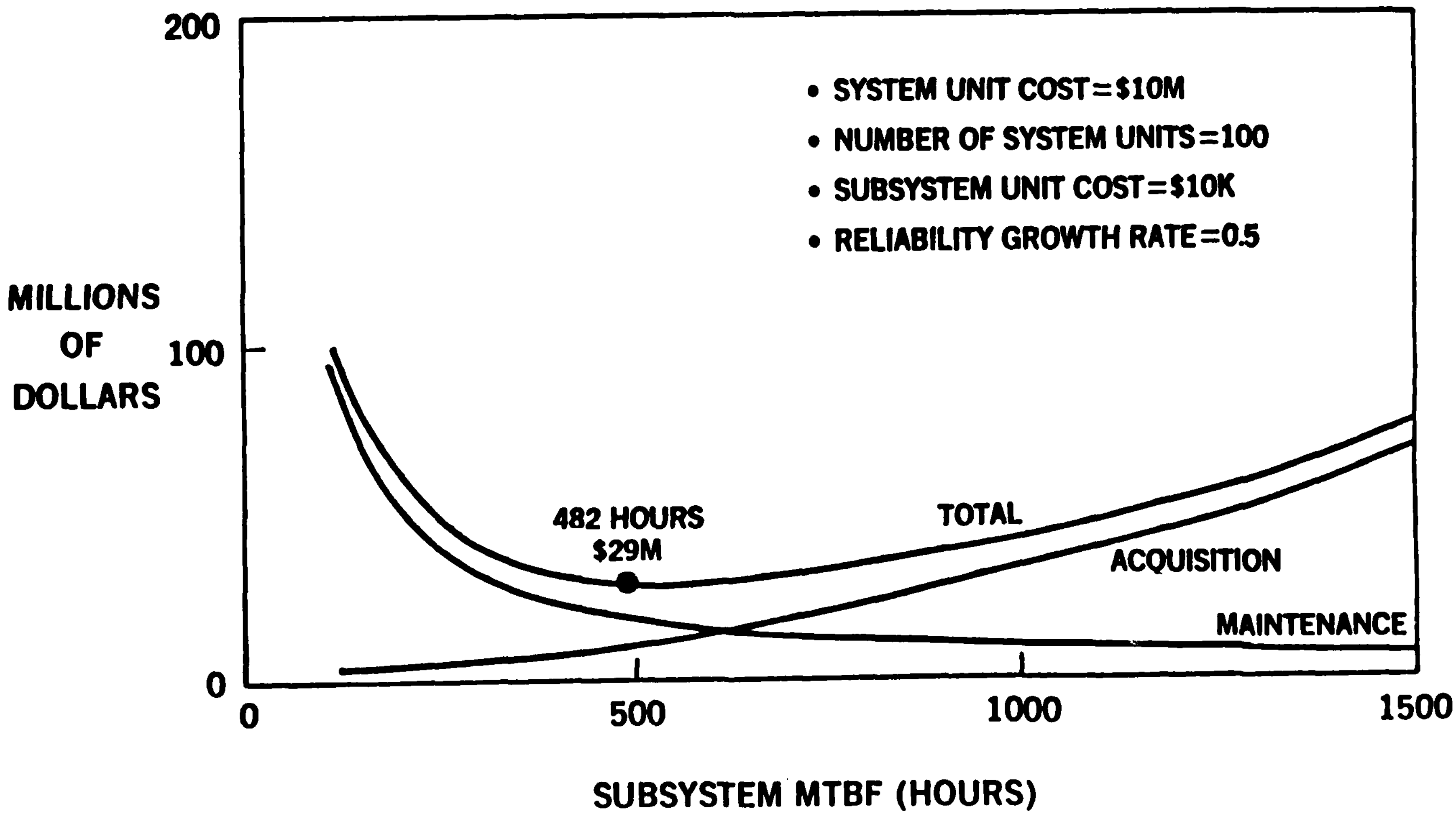
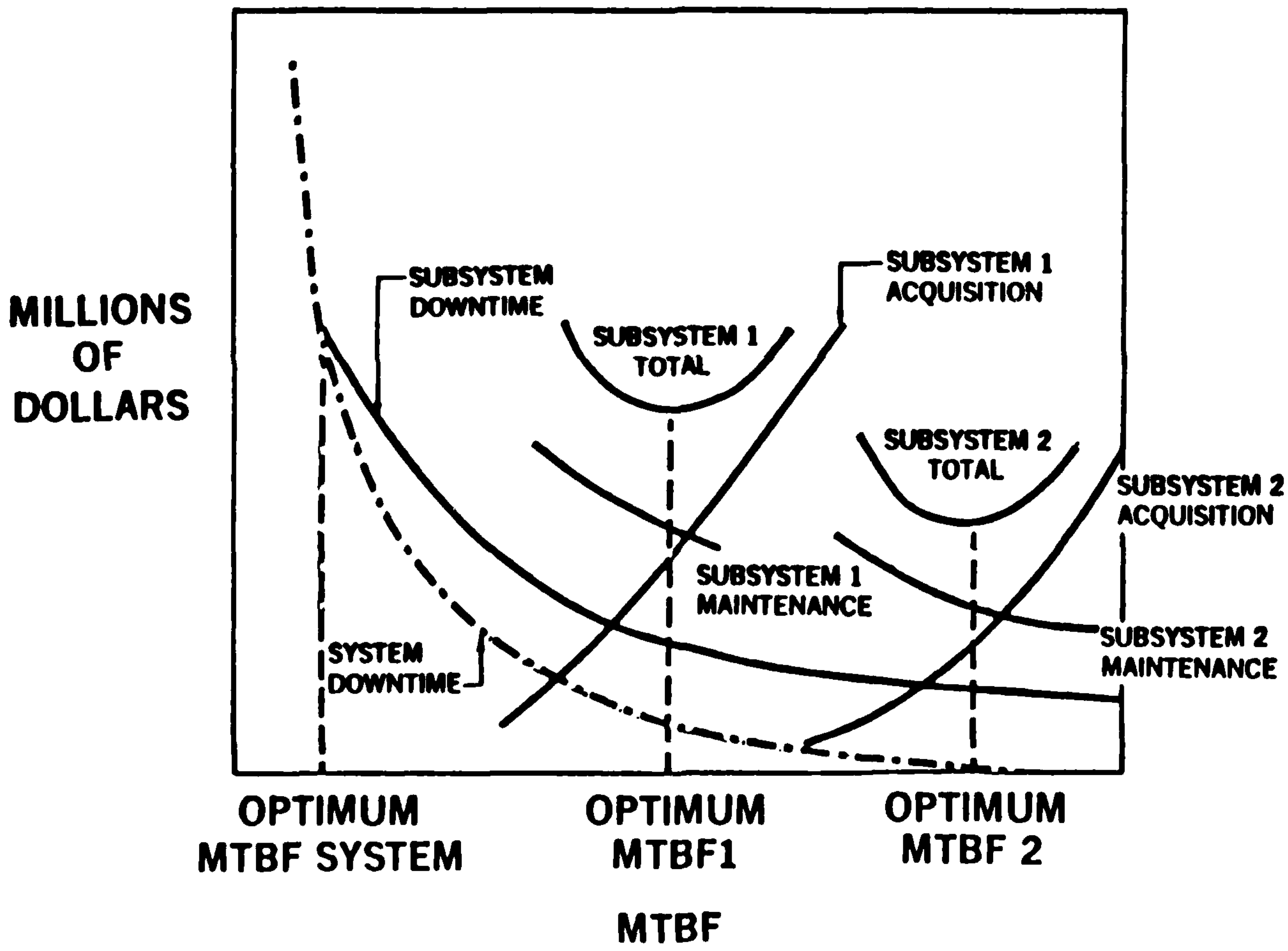


ILLUSTRATION OF OPTIMUM SOLUTION PROCEDURE



RELIABILITY — COST CASE STUDIES

	PRESENT MTBF	OPTIMUM MTBF
F-4B (635)		
LIFE CYCLE COST	$5.8B	$2.9B
PROBABILITY OF SUCCESS	57%	89%
SYSTEM MTBF	0.66 HR*	6.21 HR
F-105D (507)		
LIFE CYCLE COST	$2.2B	$1.6B
PROBABILITY OF SUCCESS	80%	90%
SYSTEM MTBF	0.26 HR*	1.04 HR

*THIS IS REALLY MFHBMA, AND DOES NOT REPRESENT CRITICAL FAILURE TIMES

RELIABILITY — COST CASE STUDIES (CONT)

	PRESENT MTBF	OPTIMUM MTBF
B-52H (100)		
LIFE CYCLE COST	\$1.7B	\$1.5B
PROBABILITY OF SUCCESS	74%	94%
SYSTEM MTBF	0.27 HR*	1.65 HR
C-141A (280)		
LIFE CYCLE COST	\$4.0B	\$2.4B
PROBABILITY OF SUCCESS	67%	95%
SYSTEM MTBF	0.54 HR*	5.6 HR

*THIS IS REALLY MFHBMA, AND DOES NOT REPRESENT CRITICAL FAILURE TIMES

ESTIMATED RETURN ON RELIABILITY INVESTMENT FOR SEVERAL AIRCRAFT WEAPON SYSTEMS

SYSTEM	ADDITIONAL INVESTMENT IN ACHIEVING OPTIMUM MTBF	PERCENT RETURN ON INVESTMENT
F-4B	$439M	669
B-52H	$ 76M	240
F-105D	$194M	299
C-141A	$271M	593

F-4C CASE STUDY

300 AIRCRAFT 10-YEAR LIFE	PRESENT MTBF	OPTIMUM MTBF
LIFE CYCLE COST	$1433M	$980M
PROBABILITY OF MISSION SUCCESS	0.343	0.797
SYSTEM MTBF	0.63*	3.33

* THIS IS REALLY MFHBMA, AND DOES NOT REPRESENT CRITICAL FAILURE TIME

F-4C CASE STUDY (CONT)

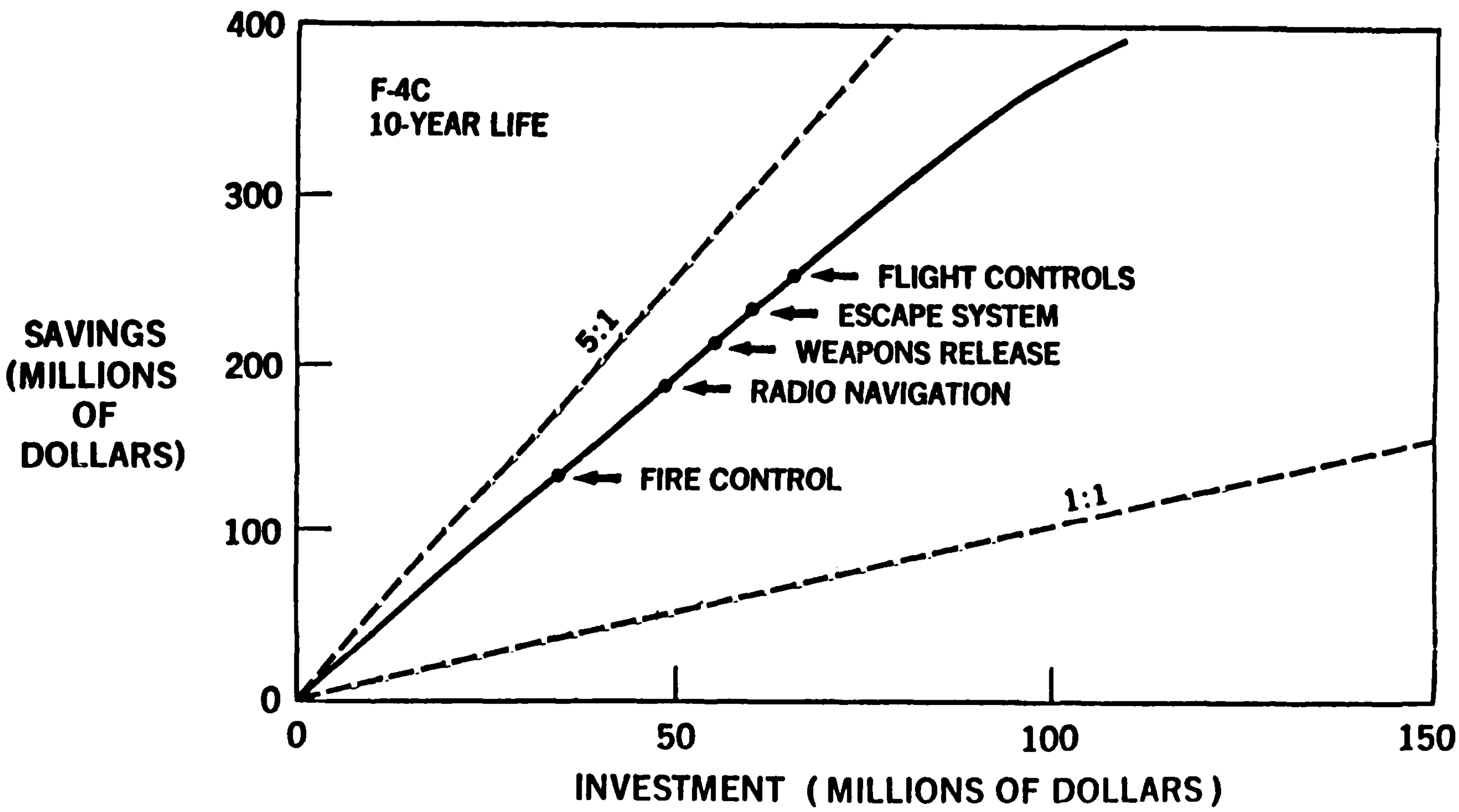
SUBSYSTEM SUMMARY**

S/S	PRESENT MTBF*	OPTIMUM MTBF	INVESTMENT ($ M)	SAVINGS ($ M)
FIRE CONTROLS	4.0	31.6	33.5	134.7
RADIO NAVIGATION	7.8	60.4	13.4	53.6
WEAPONS RELEASE	19.2	157.2	4.3	20.0
ESCAPE SYSTEM	13.0	76.9	5.7	15.8
FLIGHT CONTROLS	10.8	58.0	6.1	14.3

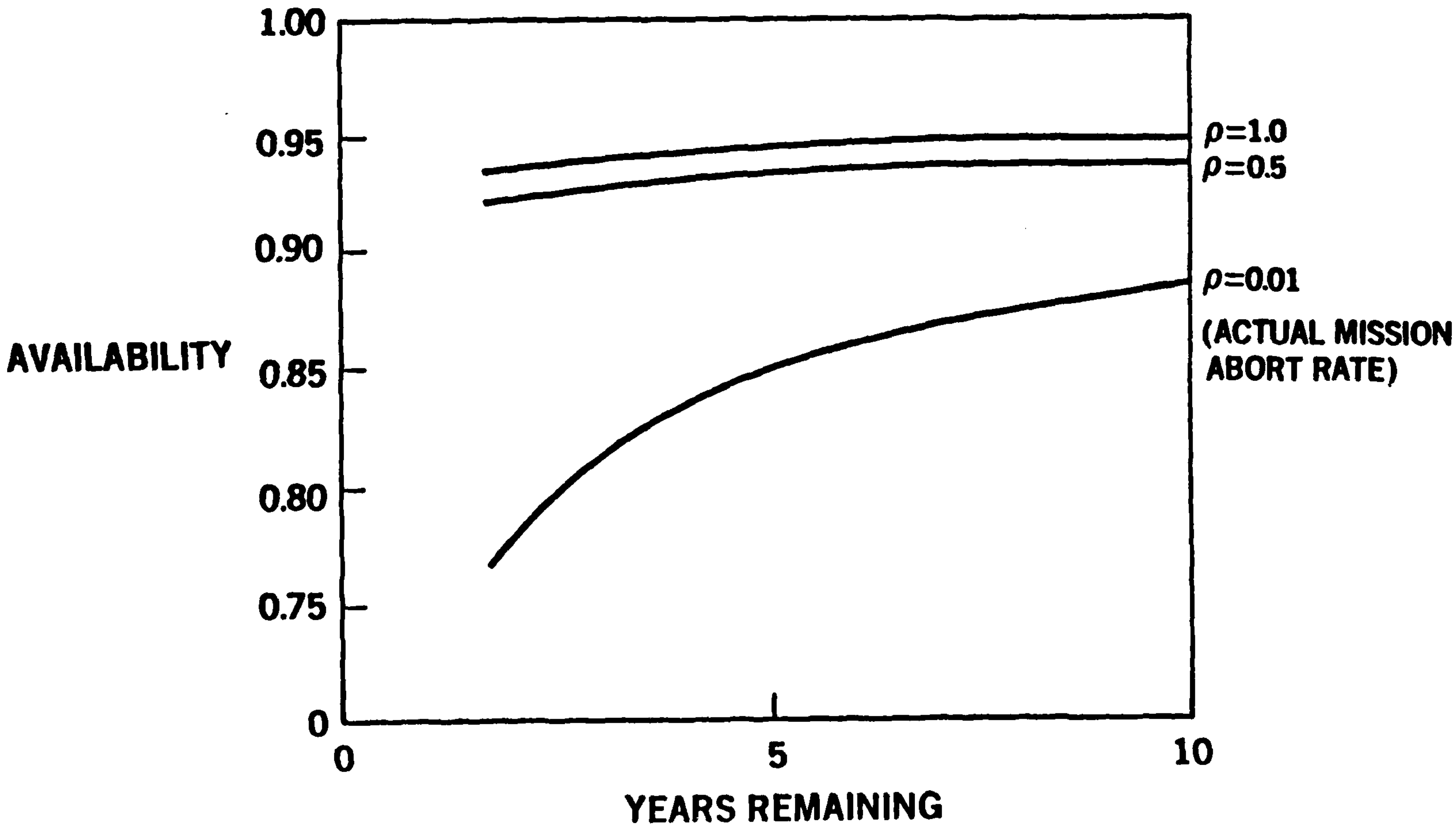
*THIS IS REALLY MFHBMA, AND DOES NOT REPRESENT CRITICAL FAILURE TIME

**AIRFRAME AND PROPULSION SUBSYSTEMS WERE NOT INCLUDED

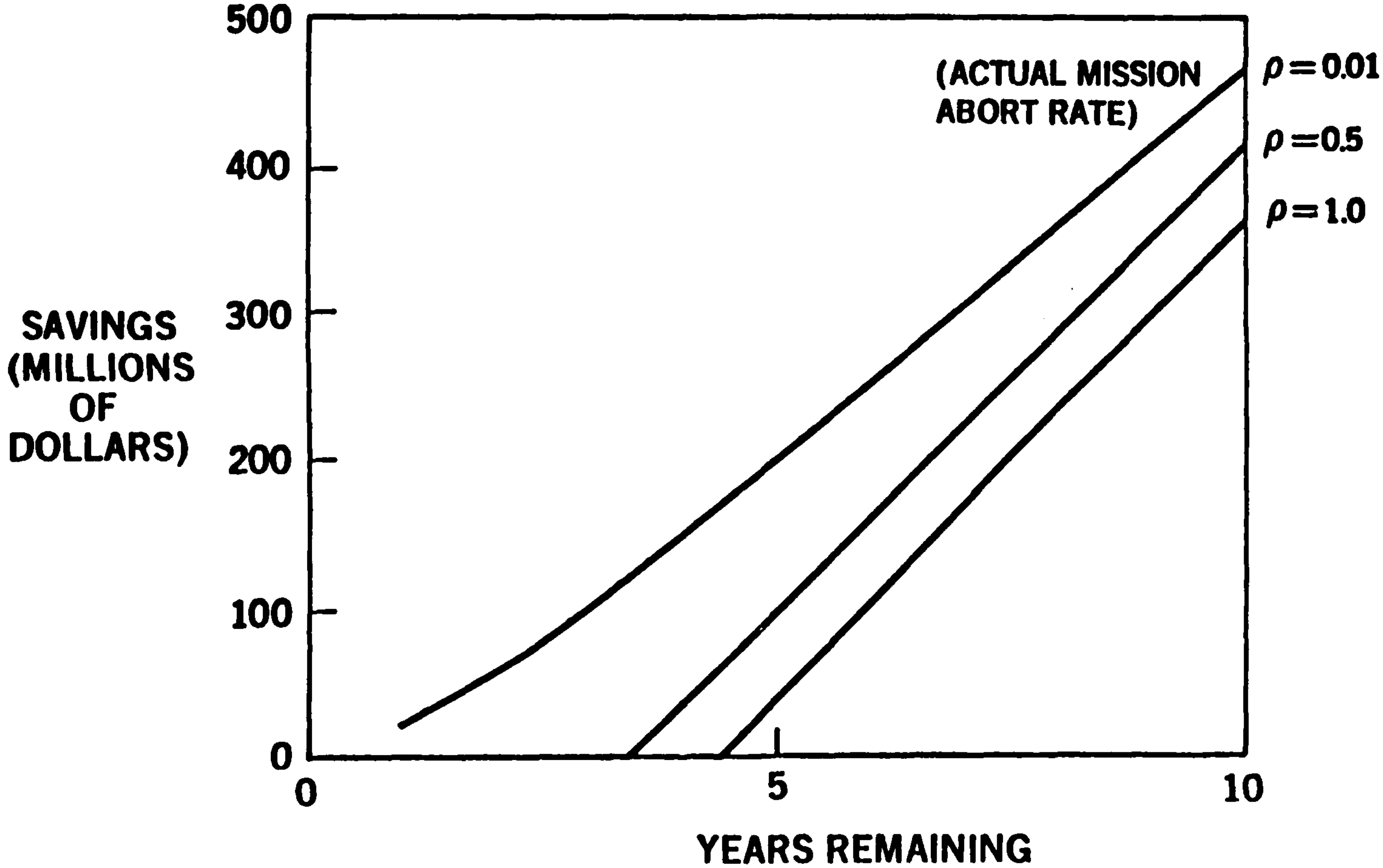
SAVINGS POTENTIAL WITH FUNDING CONSTRAINTS



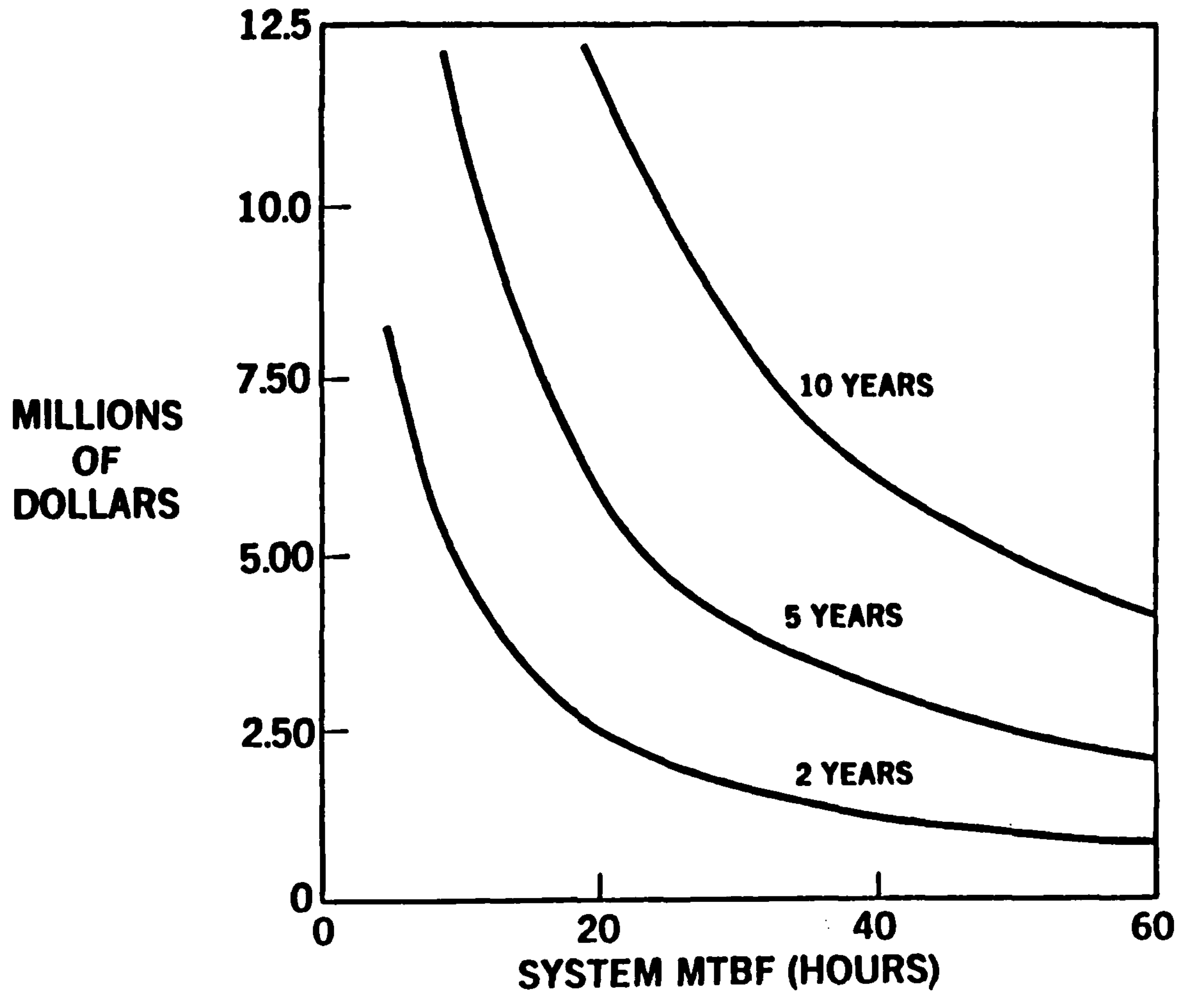
F-4C OPTIMUM AVAILABILITY



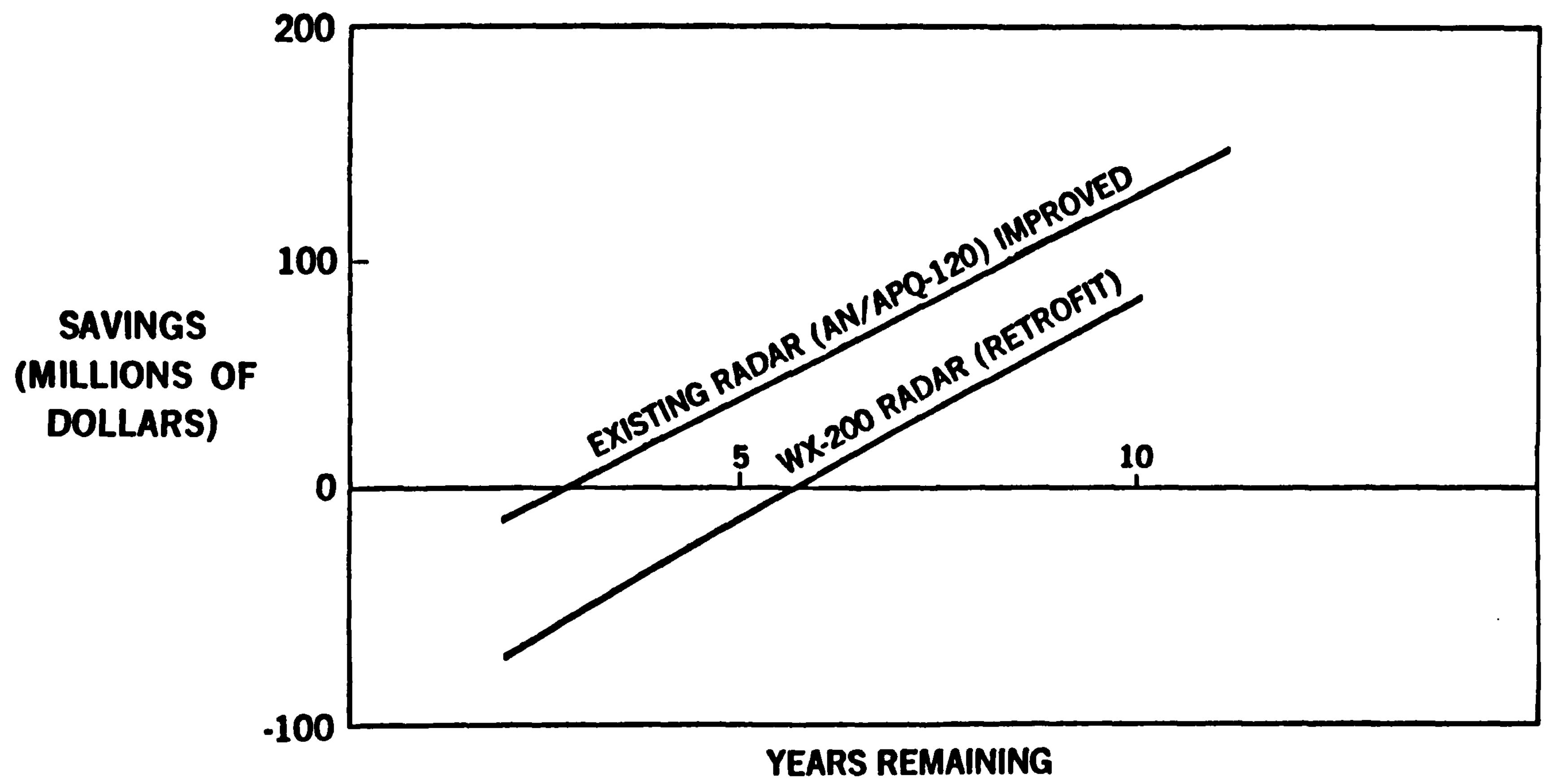
SAVINGS SENSITIVITY TO LIFE AND CRITICALITY
F-4C
300 AIRCRAFT



F-4C MAINTENANCE COST



AN/APQ-120 SAVINGS ALTERNATIVES



SUBSYSTEM CASE STUDY

AN/APQ-120 F-4E ATTACK RADAR

MTBF = 12 HOURS
AVERAGE COST PER FAILURE = $700
YEARLY COST OF FAILURES = $10,000,000

ALTERNATIVES:

1. EXISTING RADAR RETROFIT

2. NEW RADAR RETROFIT
   - WX-200
   - AN/APQ-113
   - F-15 RADAR

MODEL EXTENSIONS

- LEARNING CURVE EFFECTS ON ACQUISITION COSTS
- ATTRITION EFFECTS
- CANNIBALIZING EFFECTS ON AVAILABILITY
- OVERHAUL AND MODIFICATION EFFECTS
- DISCOUNTING
- DYNAMIC RELIABILITY
- OPTIMAL SPARES PROCUREMENT POLICY
- OPTIMAL LEVEL OF REPAIR ANALYSIS
- DESIGN REDUNDANCY

Defense Materiel Systems Life Cycle Cost Model **

**Developed and Owned by Strategic Financial Planning Systems, Inc.

THE DEFENSE MATERIEL SYSTEMS LIFE CYCLE COST MODEL*

INTRODUCTION

The Defense Materiel Systems Life Cycle Cost Model is the fifth in a series of engineering cost models developed in response to a Marine Corps requirement for a life cycle cost model which could be used in joint Service programs to insure that Marine Corps as well as the developing Service's life cycle costs would be considered. The Army subsequently identified a similar requirement and has participated actively in its development for the last several years. The current model reflects continuing design participation by users from all Services and industry to develop a model which is equally appropriate and convenient for all analysts and decision makers who must prepare or use life cycle cost estimates.

The model's basic structure is derived from the 1978 TRI-TAC Life Cycle Cost Model expanded for use on all seven major types of Defense materiel systems: surface vehicle, electronic, aircraft, ship, missile, ordnance and space.

The report structure satisfies the requirements of DoDI 5000.2, Major Systems Acquisitions Procedures, the DoD Cost Analysis Improvement Group (CAIG), Department of the Army 11 series Pamphlets and the Fiscal Director of the Marine Corps. The cost reports, with supporting documentation, are appropriate for presentation to all Services' system acquisition review councils and the DSARC.

This paper describes the analytical environment which the model is designed to support; the data bases used by the model; user experiences with the model and management of the model. Enclosure (1) contains a summary of model inputs and outputs.

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* Developed and owned by Strategic Financial Planning Systems, Inc.

UNDERSTANDING THE PROBLEM

In the late 1960s, rapidly increasing costs for new weapon systems gave impetus to the use of procurement cost as a design parameter comparable in importance to performance and schedule. Concerns about controlling acquisition costs gave rise to design-to-cost and design-to-unit-production-cost as DoD management tools. The Services soon recognized that concentration on acquisition costs without regard to ownership costs was leading to suboptimization at the expense of the user. The Services have since been attempting to incorporate life cycle costs as a design parameter, with varying degrees of success.

Life cycle costing is the systematic, analytical process of determining and listing the total cost of developing, producing, owning, operating, supporting, and disposing of materiel or weapons systems.

This process must begin as early as possible (preferably during concept exploration and no later than the demonstration and validation phase) since the opportunity to minimize the cost of ownership diminishes rapidly as the design and development of a weapons system proceeds through the acquisition cycle. It has been estimated that up to 75% of the life cycle cost is determined very early in the full scale development phase.

DoD Directive 5000.1 directs all military departments to achieve the most cost-effective balance between acquisition and ownership costs and system effectiveness, and to consider affordability at every milestone. DoD Instruction 5000.2 defines affordability as the ability of the Service to provide adequate resources to acquire and operate new systems. These directives, in conjunction with OMB Circular A-109, make it clear that the decision to procure a new weapon system, no matter how desirable, shall be dependent upon the Government's ability to fund both the procurement and the operation of the system.

Developmental systems compete for limited resources at all decision levels starting with sponsors and proceeding through the budget process to Congress. Affordability issues are closely examined many times in the developmental cycle of a system -- both in terms of the system's cost for various configurations, capabilities, uses and maintenance concepts, and in terms of the system as one of many systems vying for Service, DoD and Congressional budget dollars. At any given point in time, expected costs for all currently proposed systems far exceed expected funding levels.

The decision environment surrounding the system acquistion process is exceedingly complex. Accordingly, decisions are strongly influenced by the confidence each participant has in the available decision information, especially performance and economic data. A major objective of life cycle costing is to provide decision makers at all levels with sufficient economic information to determine, within the bounds set by affordability, both the most cost-effective configuration for individual weapon systems and the most cost-effective mix of existing and proposed weapon systems.

The development and presentation of comparable costs for all proposed systems is vital if informed acquisition decisions are to be made by the Services, DoD and Congress. As a minimum, cost estimates must be based on similar cost structures. Both cost estimates and the derivation of those cost estimates must be subject to review and agreement by those responsible for the acquisition decisions.

The preparation of life cycle cost estimates is a complex process. Analysts assigned to a myriad of organizational entities in both Government and industry develop portions of each estimate, often independently and, in may instances, without full appreciation of the estimate as a whole. Elements beyond the control of any one participant in the process influence other parts of the estimate as well as the total estimate

(e.g., schedule, operational use, manning levels, skill levels, maintenance concepts). No single cost estimating methodology (e.g., parametric, price, analogy) is universally appropriate for developing any of the individual costs which makes up the total life cycle cost picture. In this context, analysts are expected to define the resources required to develop, produce and successfully operate systems which, in many cases, have no comparable analog in the current state of either engineering or organizational art.

This environment presents the model developer with a dilemma: to create a model which is simple to use and at the same time flexible enough to deal with the wide range of analytical requirements which vary over time and between systems and which depend upon the unpredictable availability of decision relevant data. The Defense Materiel Systems Life Cycle Cost Model attacks this problem in the following ways:

1. Divide and Conquer

The model allows program managers to divide the cost problem into well defined and logically bounded parts that can be assigned to appropriately skilled analysts belonging to other organizational entities. For example, engineers can concentrate on estimating design and producibility resource requirements, as well as reliability and maintainability objectives; managers on such issues as schedule and cash flow; proponents on operational use and manning requirements; and logisticians on level of repair, training, repairability and supply support. This lets individual analysts concentrate on the subsets of each life cycle cost data set which fall within their area of expertise while the model keeps track of interdependencies with inputs made by other analysts.

2. Provide Structure, Not Method

The Defense Materiel Systems Life Cycle Cost Model provides a structure for cost analysis which accommodates simple and complex systems developed in simple or complex management environments. As noted

F. INTEGRATED LOGISTICS

5000.39	(D)	Acquisition and Management of Integrated Logistic Support for Systems and Equipment
4130.2	(D)	The Federal Catalog System
4140.19		Phased Provisioning of Selected Items for Initial Support of Weapons Systems, Support Systems, and End Items of Equipment
4140.40	(D)	Basic Objectives and Policies on Provisioning of End Items of Material
4140.42		Determination of Initial Requirements for Secondary Item Spare and Repair Parts
4151.7		Uniform Technical Documentation for Use in Provisioning of End Items of Material
4151.15		Depot Maintenance Programming Policies
5100.63		Provisioning Relationships Between the Military Departments/Defense Agencies and Commodity Integrated Material Managers

G. INTERNATIONAL COOPERATION

2000.3	(D)	International Interchange of Patent Rights and Technical Information
2000.9	(D)	International Co-Production Projects and Agreements Between the U.S. and Other Countries or International Organizations
2010.6	(D)	Standardization and Interoperability of Weapon Systems and Equipment within the North Atlantic Treaty Organization (NATO)
2010.7	(D)	Policy on Rationalization of NATO/NATO Member Telecommunication Facilities
2015.4		Mutual Weapon Development Data Exchange Program (MWDDEP) and Defense Development Exchange Program (DDEP)
2035.1	(D)	Defense Economic Cooperation with Canada
2045.2		Agreements with Australia and Canada for Qualifications of Products of Non-Resident Manufacturers

2100.3	(D)	United States Policy Relative to Commitments to Foreign Governments Under Foreign Assistance Programs
2140.1		Pricing of Sales of Defense Articles and Defense Services to Foreign Countries and International Organizations
2140.2	(D)	Recoupment of Nonrecurring Costs on Sales of USG Products and Technology
3100.3	(D)	Cooperation with Allies in Research and Development of Defense Equipment
3100.4	(D)	Harmonization of Qualitative Requirements for Defense Equipment of the United States and Its Allies
3100.8		The Technical Cooperation Program (TTCP)
4155.19		NATO Quality Assurance
5100.27	(D)	Delineation of International Logistics Responsibilities
5230.11	(D)	Disclosure of Classified Military Information to Foreign Governments and International Organizations
5230.17	(D)	Procedures and Standards for Disclosure of Military Information to Foreign Activities
5530.3	(D)	International Agreements

H. PLANS - CONSERVATION OF RESOURCES

4170.9		Defense Contractor Energy Shortages and Conservation
6050.1	(D)	Environmental Effects on the United States of DOD Actions

I. PLANS - MATERIAL AVAILABILITY, WAR RESERVE AND MOBILIZATION

3005.5	(D)	Criteria for Selection of Items for War Reserve
4005.1	(D)	DOD Industrial Preparedness Production Planning
4005.3		Industrial Preparedness Production Planning Procedures

2. DOD POLICY ISSUANCES RELATED TO ACQUISITION OF MAJOR SYSTEMS

A. DEFENSE ACQUISITION REGULATION (FORMERLY ARMED SERVICES PROCUREMENT REGULATION)

B. ADMINISTRATION - GENERAL

4105.55	(D)	Selection and Acquisition of Automatic Data Processing Resources
4275.5	(D)	Acquisition and Management of Industrial Resources
5000.4	(D)	OSD Cost Analysis Improvement Group
5000.16	(D)	Joint Logistics and Personnel Policy and Guidance (JCS Publication No. 3)
5000.23	(D)	System Acquisition Management Careers
5000.29	(D)	Management of Computer Resources in Major Defense Systems
5100.40	(D)	Responsibility for the Administration of the DOD Automatic Data Processing Program
5220.22	(D)	Department of Defense Industrial Security Program
5500.15		Review of Legality of Weapons Under International Law
7920.1	(D)	Life Cycle Management of Automated Information Systems (AIS)
7920.2	(D)	Major Automated Information System Approval Process

C. ADMINISTRATION - STANDARDIZATION OF TERMINOLOGY

5000.8		Glossary of Terms Used in the Areas of Financial, Supply and Installation Management
5000.9	(D)	Standardization of Military Terminology
5000.11	(D)	Data Elements and Data Codes Standardization Program
5000.33		Uniform Budget/Cost Terms and Definitions

D. COMMUNICATION/INFORMATION MANAGEMENT

5000.19	(D)	Policies for the Management and Control of Information Requirements
5000.20	(D)	Management and Dissemination of Statistical Information
5000.22		Guide to Estimating Cost of Information Requirements
5000.32		DOD Acquisition Management Systems and Data Requirements Control Program
5230.3	(D)	Information Releases by Manufacturers
C-5230.3	(D)	Public Statements on Foreign and Military Policy and on Certain Weapons (U)
5230.4	(D)	Release of Information on Atomic Energy, Guided Missiles and New Weapons
5230.9	(D)	Clearance of Department of Defense Public Information
5400.4	(D)	Provision of Information to Congress
5400.7	(D)	Availability to the Public of Department of Defense Information

E. CONTRACT MANAGEMENT

1100.11	(D)	Equal Employment Opportunity, Government Contracts
4000.19	(D)	Basic Policies and Principles for Interservice Interdepartmental and Interagency Support
4105.60		Department of Defense High Dollar Spare Parts Breakout Program
4105.62	(D)	Selection of Contractual Sources for Major Defense Systems
4140.41		Government-Owned Material Assets Utilized as Government-Furnished Material for Major Acquisition Programs
4160.22	(D)	Recovery and Utilization of Precious Metals
5010.8	(D)	DOD Value Engineering Program
7800.1	(D)	Defense Contract Financing Policy

APPENDIX A

BASIC STATISTICAL PROCEDURES FOR LIFE CYCLE COST ANALYSES

APPENDIX B

KEY DOCUMENTS GOVERNING MILITARY SYSTEM PROCUREMENT

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OUTPUTS

The analyst can select any or all of the following reports:

- Budget reports by appropriation, life cycle phase and year
- R&D costs (hardware and software)
  - Government
  - Contractor
- Production costs (hardware/software)
  - Government (recurring and non-recurring)
  - Contractor (recurring and non-recurring)
- Unit production costs
- Operations and maintenance costs
- Material consumption costs
- Energy consumption costs
- Operator/crew costs
- Operational transportation costs
- Software maintenance costs (maintenance & diagnostic software and operational software)
- Equipment maintenance costs
  - Facilities
  - Spares
  - Repair parts by level of maintenance & WBS class
  - Personnel
  - Transportation
- Supply personnel and facility costs
- Personnel support costs
- Life cycle cost by phase by year
- Comparison of inflated vs constant dollars by phase & year
- Number of annual failures for each WBS item
- Number of maintenance manhours by level for each WBS item
- Excesses and shortfalls for the projected maintenance T/O
- Material consumption by class of supply
- Report of cost elements which differ between any two runs
- Analyst created footnotes for each report
- GFE data base to include cost and maintenance concept
- Mission profile data base for all major type force units

APPENDIX A

SELECTED REFERENCES

A. Human Factors, Manpower, Personnel, and Training

B. Life Cycle Cost Analysis

- Optimal stock levels.
- Logistics Analysis Support Records (LSARs).
- Cost uncertainty analysis.
- DTUPC tracking.
- Minimum input mask.
- Historical cost data base with CER generator.
- CER submodels.

INPUTS

The following is a summary of the input classes which can be used with the model. The user can elect to use any or all of these inputs, but generally only a subset is required for any one program.

- o R&D activity costs, schedule and spending rates
- o Production activity costs, schedule and spending rates
- o WBS item costs and descriptions to any level of indenture
- o Deployment scenarios
- o Up to 25 different tables of organization/equipment
- o Maintenance scenarios down to the piece part level for each table of organization/equipment from operator to depot level
- o Manpower requirements (grade, MOS, Service, numbers)
  - R&D and production activities
  - Operators/crew
  - Indirect command personnel
  - Organizational maintenance
  - Intermediate maintenance/DSU maintenance (including contact teams)
  - GSU maintenance (including contact teams)
  - Software maintenance (maintenance and operational software)
- o Manufacturer's manpower cost structure (optional)
- o Transportation (operations, maintenance)
- o Inflation (DoD, Service specific, and Bureau of Labor Statistics (BLS) commodity deflators)
- o Facilities
  - R&D, Industrial, Test
  - Operational
  - Maintenance
  - Software
  - Supply
- o Free text comments for each life cycle phase (optional)

control, intelligence, tracked and wheeled vehicle, chemical and ordnance systems for the Army, Marine Corps and the Air Force. Analysts from Government, prime contractor, sub-contractor and support contractor organizations are active users. It has been used for baseline and independent cost estimates during concept formulation, full scale development, in support of the production decision and for post-production product improvement programs.

As a result of intensive use by a variety of subscribers with different perspectives, a number of improvements have been made to make the model more user friendly and easier to understand. These changes were designed to enable analysts to focus on the cost analysis problem and not on the model itself.

User feedback has emphasized the following advantages of the model:

o The model has lead to increased dialogue between Government and contractor personnel to clearly define Government controlled cost drivers associated with operations and maintenance and thus providing realistic parameters for system design trades.

o Because the model is well defined and easy to use, analysts have been able to devote proportionally more of their time to developing and refining their cost estimates.

o Electronic transfer of data between users has allowed analysts at different sites to share current estimates and to develop joint positions prior to submitting final reports.

o Prime contractors have used the model for proposal preparation to make preliminary estimates of the most cost-effective mix of available hardware choices and to insure that cost estimates include all of the items to be charged to the program.

o The Government has used the model to advise contractors of baseline hardware configurations and maintenance concepts for initial trade studies and for use in follow-on proposals.

o Large data bases can be created quickly by combining existing data bases and by using the copy functions available in the editors.

o Both Government and contractor analysts have used the model for level of repair studies.

o Final study reports can be prepared quickly and can easily be modified since the model can produce the reports in the required format, this includes the data bases as well as the cost reports.

o The budget reports produced by the model have been used to create the O&M wedge in the outyears to insure that sufficient O&M dollars are available to the new system.

o Average analysts take about 2-4 days to become proficient in using the model.

TRAINING

A three-day course is available to subscribers to train a cadre of analysts. This course is tailored to the skill level of the new users and covers the the basics of life cycle costing, the model, setting up terminals at the user's site and defining a preliminary data base for one of the users current systems.

FUTURE DEVELOPMENTS

The life cycle cost data base is similar to, and, in many cases, identical to that required for the Logistics Analysis Support Record, Level of Repair Analyses, Project Status Reporting and PERT/CPM. Having separate programs and data bases for each of these major analytical and management control techniques can complicate the management of major systems and is not cost-effective. Enhancements which have been proposed to take advantage of these data redundancies include:

o Level of Repair Analysis (LORA) to include least cost (optimal) level of repair paths for each end item.

telephone line. By creating a job control file, the model may also be run in background, reducing processing costs by 50%. Only a printing terminal with a modem is required to use the model. 1200 baud terminals are preferable to reduce run times and to minimize charges.

SECURITY

All users are assigned password-protected user numbers. All user-created files may be password-protected by the user. Except by special permission, files may only be accessed by using the same user number which was used to create the file. No user has access to another user's files except by special permission of the owning user for purposes of transferring data electronically. All files are backed up to tape daily, weekly and monthly. System personnel cannot access password-protected files. Data files are stored in binary code so that they cannot be listed except by the model.

RESPONSIVENESS

Complex systems can be entered in 8 to 12 hours. The model is interactive and the normal compute time is 7 to 20 seconds. The model may be run in either interactive or batch modes. Batch processing reduces the costs for system resources by approximately 50%.

REFERENCE DOCUMENTATION

Documentation includes a Data Collection Workbook and Operating Instructions. The Data Collection Workbook defines each cost element, cost factor and equation to simplify and organize the data collection effort, to minimize errors due to double counting or misunderstanding and to facilitate the preparation of comparable estimates. The Operating Instructions present a tutorial discussion and overview of the model using annotated runs of an actual terminal session.

UPDATES TO MODEL DATA BASES

Personnel costs, training costs and DoD deflators are available to all users in data bases maintained with Government data. Inflation indices are updated every six months and the personnel data bases are updated annually.

CONFIGURATION MANAGEMENT

The model is written in FORTRAN. The same copy of the compiled model is shared by all users. No user can make changes to the model itself. User reported errors are investigated and corrected upon verification. Users are advised by electronic mail through their user numbers of all changes which could impact on their results. Change pages to reference documentation are forwarded to all users.

Major revisions to the model are released as new versions after extensive testing and verification. A configuration control board reviews all proposed changes to the model or the Government data base.

INTERFACES TO OTHER MODELS

Interface programs can be developed for users who desire to use their own software to predict cost elements used by the model. These are particularly useful for users who have regression-based equations to predict hardware costs or who have bill-of-material data bases. The interface programs are written in FORTRAN and may be run in background or interactively, depending upon the user's needs. Interface programs can be provided to users so that they can modify them to suit their own needs.

USER EXPERIENCE

Various versions of the model have been in use since 1979. It has been used to cost a wide variety of communications, command and

Inflation

The inflation data base contains password-protected DoD deflators for R&D, Production, O&M, Other Procurement, MILCON and Military Personnel budget categories. Program-specific deflators may be optionally entered and used for each of these categories. Analysts may also enter Bureau of Labor Statistics (BLS) or other deflators for equipment furnished under contract. WBS items may be entered in different year dollars. (This is especially useful for GFE which is often reported in a variety of year dollars.) The model uses the inflation rate tables to normalize all input costs to the system base year. Reports may be produced in constant and current (inflated) dollars using this data base.

Personnel

Personnel are entered as Tables of Organization (T/Os) classified by Service, grade, MOS, job function and number. T/Os may be entered for each phase of the life cycle: R&D, Production, Operations and Maintenance. The model calculates manhour demand for up to 21 different functional areas and converts these to billet costs using both DoD and Service billet cost tables for DoD personnel (military and civilian) and manufacturer's pay scales for contractor personnel. Personnel may be dedicated to the system (i.e., fully charged regardless of demand) or shared (i.e., only charged for work demanded by the model). Multiple Services may be entered. The analyst may allocate subsets of the T/O to operate or maintain specific equipment subsystems. There is no limit to the number of T/Os or personnel who may be entered.

Training

Both course cost and training track data bases may be created by the analyst. Costs for the training track may be substituted for MOS training costs in the model's data bases for selected lines in the T/O. Costs for selected formal Service schools are included in the model's data bases. Analysts may create training tracks which are a combination of current Service schools, civilian schools and proposed Service schools. On-the-job training is normally not charged to the system.

EDITORS

Powerful editors are provided which allow the analyst to create new records by copying selected parts of existing records or to quickly and easily change data items in existing records. These editors allow the analyst to take advantage of the redundancies found in any life cycle cost data base (e.g., common maintenance profiles) to reduce the amount of data which must be entered through a terminal. The editors also make it a relatively easy task to create a new system by copying selected parts of existing data bases, assembling these parts into a new data base and then making appropriate revisions to reflect those factors which distinguish the new system from the existing system. These editors also perform preliminary quality control checks on data as it is entered.

SENSITIVITY

The model is sensitive to equipment design, manufacturing methods, reliability and maintainability, operational use, maintenance profile, manpower requirements and schedule. The model can be used to predict both cost element and life cycle cost implications of changes in:

- Manufacturing technology
- Design (hardware/software)
- Operational use
- Maintenance philosophy
- Manpower requirements
- Training requirements
- Schedule (R&D, production, deployment)
- POM/budget requirements

ACCESS

The Defense Materiel Systems Life Cycle Cost Model is interactive and is available to users worldwide through TELENET, TYMNET and leased

above, the model allows the program manager total freedom to select those costs which should be included in any given estimate. The model allows the analyst the same freedom to pick a mixture of cost estimating methodologies most appropriate to the analysis, schedule and available data: parametric, analogy, engineering, expert opinion or market price. There are several major advantages to this approach:

o Independent estimates can be made using the same set of assumptions, thus allowing analysts to focus on estimating methods rather than on structure.

o The analyst is not forced to use dated or inappropriate parametric cost estimating relationships (CERs) or procedures.

o Data entry is simplified since only data required for the analysis is required. Dummy data to make an inappropriate CER work is not required.

o Competitive sensitive methodologies (Government or industry) are protected.

o The most relevant cost estimating methodology can be selected for each estimate over time allowing the analyst to use a mixture of high and low resolution estimating procedures.

o Model maintenance costs are minimized.

o The model can be used for any type of system during all phases of its developmental cycle to include product improvement programs.

o The model is easy to use since the cost estimating methodology is selected by the analyst, not the model.

o The model does not require re-validation before each new application since it is not a parametric cost model.

3. Fit the Level of Detail to the Decision Requirement

The decisions which use life cycle cost estmates are as disparate as they are complex. For example, engineering trades generally

require a focused level of detail which is sensitive to the variables being examined. Program management decisions are generally concerned with broader, less detailed estimates.

The model allows analysts to select the amount and level of reporting detail which best fits their own decision space. This recognizes that decision aids should aid decision makers and not add to the problem with unneeded data.

4. Produce Comparable Results

Since the model treats all classes of material systems from tanks to ships comparably, the results of the analyses conducted by different program managers can also be used to make trade-offs between competing weapon systems at the Service, DoD and Congressional decision levels.

MODEL DATA BASES

The analyst has complete control over the contents of all data bases except the files which contain OSD inflation rates and manpower cost factors such as pay and allowances, base operating support, medical, and retirement liability which are set by the individual Services. Each of the model's data bases is discussed briefly in the following paragraphs.

System: (R&D, Production)

System level costs address such areas as program management, system test and evaluation, data, facilities and training during R&D and production. These costs may be entered in detail or at summary levels, depending upon the availability of data. Government and contractor efforts are identified separately.

System: (Operations, Assumptions)

The operations data base is used to develop system costs for maintenance and operational transportation, facilities (operational, maintenance and supply), software support (operational and maintenance and diagnostic software), contract support requirements and technical data revisions. An assumptions data base is provided for factors which apply to all end items in the system such as years of operation, manpower productivity, supply pipeline times and transportation costs by mode.

Hardware/Software

This data base is the key to the versatility of the model since the system/commodity peculiar data is resident in this file.

Hardware and software items are classified according to the project summary work breakdown structures (WBS) in MIL-STD 881A and the DA 11 series pamphlets. The hardware/software work breakdown structure data base may be created at any level of detail down to the piece parts used in the system. This data base provides information essential to judging cost realism for R&D and Production efforts as well as operating and support costs. The model accepts activity costs or level of effort estimates for labor by type (e.g., engineering, manufacturing and management), tooling, and material (e.g., raw material, purchased parts and government furnished equipment (GFE)) needed to design, develop and build prototype, pre-production and production end items.

There is no limit to the size of the Hardware/Software data base.

Learning Curves

Separate learning rates may be specified for each item and different learning rates may be used for labor and material. The model computes the effect of learning based on lot size, production schedule and production history. Both cummulative-average and unit cost theory may be used for different end items and subassemblies.

Maintenance/Operational Profiles

Each item in the hardware/software data base may be assigned a unique or common maintenance profile. The model can be used to refine maintenance concepts for end items, secondary reparables and discardable items using any mix of the maintenance concepts employed by the Services. For complex systems or systems integrated into other systems, the items being costed frequently have a variety of operational and maintenance profiles which are a function of the type command and Service. The model allows the analyst to separately describe each of the operational and maintenance profiles applicable to each end item and its components. This allows analysts to conduct trade studies which are sensitive to the entire range of operational and maintenance profiles applicable to the system and not some average pseudo profile created for analytical purposes.

Supply

The model calculates demands for major classes of supply based on the operational scenario: repair parts, POL, ammunition, electricity and all other supply items applicable to the system. The demand curve created by the schedule builds up supply system requirements as the system is deployed to using units.

Schedule

The schedule data base is used to determine cash flow requirements from Milestone 0 to disposal. This data base is also used to build up the operational equipment density table to insure accurate projections for O&M costs during equipment phase-in and phase-out, as well as for scheduling depot overhauls. Production schedules are entered separately for each lot; this allows inflation factors to be applied to each production run to insure that changes in schedule and individual Service procurements are properly costed when presented in current-year (inflated) dollars.

4005.16	(D)	Diminishing Manufacturing Sources and Material Shortages (DMSMS)
4100.15	(D)	Commercial or Industrial-Type Activities
4151.16	(D)	DOD Equipment Maintenance Program
4210.1		Department of Defense Coded List of Materials
4210.7		Controlled Materials Requirements
4210.8		Department of Defense Bills of Materials
4410.3		Policies and Procedures for the DOD Master Urgency List (MUL)
4410.4	(D)	Military Production Urgencies System
5160.54	(D)	Industrial Facilities Protection Program - DOD Key Facilities List
5220.5	(D)	Industrial Dispersal

J. PRODUCTION, QUALITY ASSURANCE, TEST AND EVALUATION

4155.1	(D)	Quality Program
4200.15		Manufacturing Technology Program
5000.3	(D)	Test and Evaluation
5000.34	(D)	Defense Production Management
5000.38	(D)	Production Readiness Reviews
5010.20	(D)	Work Breakdown Structures for Defense Material Items
5160.65	(D)	Single Manager Assignment for Conventional Ammunition

K. RESOURCE MANAGEMENT

7000.1	(D)	Resource Management Systems of the Department of Defense
7000.2		Performance Measurement for Selected Acquisitions
7000.3		Selected Acquisition Reports (SAR)

7000.10		Contract Cost Performance, Funds Status and Cost/Schedule Status Reports
7000.11		Contractor Cost Data Reporting (CCDR)
7041.3		Economic Analysis and Program Evaluation for Resource Management
7045.7		The Planning, Programming and Budgeting System
7200.4	(D)	Full Funding for DOD Procurement Programs

L. TECHNICAL MANAGEMENT - GENERAL

1130.2	(D)	Management and Control of Engineering and Technical Services
4630.5	(D)	Compatibility and Commonality of Equipment for Technical Command and Control, and Communications
5010.12		Management of Technical Data
5010.19	(D)	Configuration Management
5100.30	(D)	Worldwide Military Command and Control Systems (WWMCCS)
5100.36	(D)	Department of Defense Technical Information
5100.38		Defense Documentation Center for Scientific and Technical Information (DDC)
5100.45		Centers for Analysis of Scientific and Technical Information
5200.20	(D)	Distribution Statements on Technical Documen
5200.21		Dissemination of DOD Technical Information
7720.13		Research and Technology Work Unit Informatio System
7720.16		Research and Development Planning Summary (DD Form 1634) for Research and Development Program Planning Review

M. TECHNICAL MANAGEMENT - DESIGN PARAMETERS

3224.1	(D)	Engineering for Transportability
4100.14		Packaging of Material

4120.3	(D)	Defense Standardization and Specification Program
4120.11	(D)	Standardization of Mobile Electric Power Generating Sources
4120.18	(D)	Metric System of Measurement
4120.19		Department of Defense Parts Control System
4120.20		Development and Use of Non-Government Specifications and Standards
4120.21	(D)	Specifications and Standards Application
4140.43	(D)	Department of Defense Liquid Hydrocarbon Fuel Policy for Equipment Design, Operation, and Logistic Support
4151.1	(D)	Use of Contractor and Government Resources for Maintenance of Material
4151.9		Technical Manual (TM) Management
4151.11		Policy Governing Contracting for Equipment Maintenance Support
4151.12		Policies Governing Maintenance Engineering within the Department of Defense
4500.37		Ownership and Use of Containers for Surface Transportation and Configuration of Shelters/ Special-Purpose Vans
4500.41		Transportation Container Adaptation and Systems Development Management
C-4600.3	(D)	Electric, Counter-Counter Measures (ECCM) Policy (U)
4630.5	(D)	Compatability and Commonality of Equipment for Tactical Command and Control and Communications
5000.28	(D)	Design-to-Cost
5000.36		System Safety Engineering and Management
5000.37		Acquisition and Distribution of Commercial Products
5100.50	(D)	Protection and Enhancement of Environmental Quality